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OPERATIONAL RESEARCH QUARTERLY

Issued by the

Operational Research Club, London

VOL. 2 1951.

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EDITORIAL NOTES

PRODUCTIVITY MEASUREMENT

THE meeting to discuss productivity measurement which is to be held on March 21st under the auspices of the Operational Research Club, with Sir Henry Tizard, F.R.S., as chairman is, we believe, an important event. The urgent economic need for this country to increase its industrial productivity is all too evident. But just how the fruitfulness of the productive effort is to be assessed and in consequence directed is another problem, which has yet to be thrashed out. It may not be out of place, therefore, if we try to pose and answer some elementary and fundamental questions on productivity measurement, particularly for the benefit of the majority of our readers who will be unable to attend the meeting.

We may ask, then:

What is productivity measurement?
Why do it?
Who does it?

The key question which is missing, "How is it done?" cannot be dealt with here. We may hope to answer it in the report of the meeting that will appear in our next issue.

What is Productivity Measurement?

It is generally accepted in the United Kingdom that productivity is the measure of performance, a measure of the relationship of output of goods or services to the several elements of input, which can be classified as labour, capital, land and organisation. The term is most often used without qualification, however, to refer to productivity of labour. As well over half the cost of the national output consists of wages and salaries, this is a very important relationship when considered at the national level. From the point of view of the individual manufacturer, on the other hand, labour represents only one cost

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element. His cost figures alone cannot usually tell him how far his utilisation of labour is economic, and he must rely upon productivity data for this information. Such data obviously do not give him the whole picture, and indeed may present the possibility of achieving productivity increases in terms of labour only at the expense of using more of other resources.

Workers in this field are therefore concerned, so far unsuccessfully, to evolve methods by which the use of other elements of input on production could also be taken into account. Several have been suggested, as for example that put forward by Sir Ewart Smith and Dr. R. Beeching in a paper in 1948 to the British Institute of Management, proposing to relate the volume of output not only to the manpower directly employed, but also to the manpower equivalents of capital equipment, of services received (e.g., power) and of changes in raw materials.

For a number of specific enquiries other concepts of productivity than that of output per worker are used. These relate other elements of input to output or performance. Some enquiries, for example, are interested in machine efficiency rather than labour efficiency; others are concerned with the important problem of the efficient utilisation of particular materials such as fuel or iron ore. Another approach is that favoured by the British Institute of Management which proposes to suggest for use by medium and small manufacturers not one, but a large number of indices based on ratios between varying combinations of factors which together may give an idea of the degree of managerial effectiveness as well as of reasons of the variations.

Why Measure Productivity?

The usefulness of having a measure of the utilisation of resources, especially of labour is obvious enough. At the national level this is recognised by the annual Economic Surveys issued by the government. These contain estimates of past productivity trends and anticipated changes which form an important element in determining the nation's future output and thereby the future level of investment, imports or even of tax levels. At the level of individual industries, the usefulness of productivity measurement is well expressed in the introduction to the Anglo-American Council on Productivity's report, " Productivity Measurement in British Industry ", reviewed on another page:

> " Productivity measurement is perhaps most widely used for the study of time trends. Figures relating to the performance of a group of factories, a single factory, a department or individual operators are collected and examined at regular intervals. Fluctuations in these figures may indicate where inefficiencies are to be found and where improvements are possible; progress towards predetermined targets can be measured and generally interest in productivity is stimulated ".

Productivity measurement, however, is not necessarily directed to the study of time trends. It may be directed to finding a measure of efficiency between different organisations. Mr. L. H. C. Tippett has described in this quarterly (1, No. 2, p. 19) the efficiency surveys carried out by the Cotton Industry Research Association, in which

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the concept of O.H.P. (the operative hours required to produce 100 lb. of yarn) plays an essential part.

> "The results", writes Mr. Tippett, "for any one mill are not very informative to the industry at large, but when those for many mills are collated, information emerges which can be put to practical use. From the O.H.P. required in each department for producing each count of yarn (count is a measure of fineness . . .) averaged for the whole industry, it has been possible to estimate the average effect on labour requirements of the various forms of re-equipment available to the industry; and for each form of re-equipment an index has been calculated consisting of the ratio of the percentage saving in labour to the capital cost involved. . . . It is approximate, and applies only very roughly to any given mill; and it helps managements only in choosing between alternative forms of re-equipment. It should not and probably has not been rigidly used by any management in coming to decisions, but it provides a rough basis and a method of approach to the problems."

Similarly comparisons of productivity levels can be made between corresponding industries in various countries, as one of the guides of relative technological progress and their relative competitive power. Such comparisons were made on a national and industry basis in the studies of Dr. L. Rostas which called attention to the great differences in output per man-hour between American and British industries. These findings were later confirmed by the reports of the various teams visiting the United States under the ægis of the Anglo-American Council on Productivity. A good example of the use made of international comparisons on a "firm" basis are the inquiries of Courtauld's in plants in a number of countries, described in the booklet quoted above.

Productivity of labour is regarded as a measure of general efficiency in the use of labour and not of the effort of the labour, as a recent pamphlet on Terminology of Productivity issued by the Organisation for European Economic Co-operation points out. It is influenced by the combined effect of a large number of separate though interrelated factors such as the amount and quality of equipment employed, technical improvements, managerial efficiency, the flow of materials and components, the relative contributions of units at different levels of efficiency as well as the skill and effort of the worker.

Some special inquiries, e.g., those initiated by the Human Factor Panel of the Committee on Industrial Productivity, are mainly concerned with the importance of the last factor only, i.e., the effort of the worker. Again this element is the important factor in work measurement (i.e., time and motion studies) and it is becoming obvious that the results of work measurement will play an important role in productivity measurement on the plant level. A good general illustration of this development is the interim report on the measurement of productivity issued by the Joint Committee of the Institution of Production Engineers and the Institute of Cost and Works Accountants which raised the problem of the objectivity of time study rating practice, as a precondition of productivity comparisons, and led to a national survey of this problem by the Department of Pro-

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duction Engineering of the University of Birmingham. The application of work measurement results in productivity measurement is shown in the account of the work of Joseph Lucas Ltd. in his field described in the booklet already quoted.

Who Measures Productivity?

Productivity measurement is important at many levels in the economic and industrial scene. Interested bodies who have already done some work are similarly stratified.

Government departments concerned with framing general economic and industrial policy are interested in national and industrial trends and in international comparisons. The Board of Trade is one of these departments. The general economic problems are also in the foreground of some of the academic studies, such as those carried out at the Universities of Oxford, Cambridge, Manchester and Glasgow.

At the industry level the work of the co-operative research associations, which involves the Department of Scientific and Industrial Research, is important. Well-known examples are those carried out by the Shirley Institute on cotton textiles, and by the British Boot, Shoe and Allied Trades Research Association and the British Ceramic Research Association in their respective industries. The government departments concerned with single industries have also done work of this nature as, for example, that carried out on coal mining and building. A few trade associations, such as the British Iron and Steel Federation, have also done some work in this field. Lastly, a number of professional organisations as well as the British Institute of Management are concerned with measurement techniques on an industry and plant basis

At the level of individual factories or groups of factories an interesting cross-section is provided by the Anglo-American Council's report. In the various papers some experiences of Joseph Lucas Ltd., Courtaulds Ltd., the United Steel Companies Ltd., an anonymous firm "controlling some 30 factories with workpeople ranging from 70 to 3,000", and Thos. Taylor & Bros. Ltd. (a Wigan cotton mill) are discussed.

Altogether it appears that a varied group of people, trained in different disciplines, are taking an interest in productivity measurement; economists, industrial statisticians, scientists, production engineers, cost accountants, industrial psychologists and probably others. Productivity problems at the national level call for the concepts and methods of approach of the economist, and at the industry and plant level for those of the cost accountant and work study engineer. In all phases the statistical method is essential. The technologies of the various industries, of course, enter into their respective pictures as well.

It would therefore appear that productivity measurement is a form of operational research on any of the several definitions that we have seen. Indeed, it appears a singularly urgent and favourable occasion for the adoption of the scientific method to provide executives at any level, national or industrial, with the data on which to base their decisions.

Copies of the O.E.E.C. pamphlet on the Terminology of Productivity are available, free of charge, from the editors.

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OPERATIONAL RESEARCH IN THE BUILDING INDUSTRY

by J. KNOX, M.A.

(Formerly of the Building Research Station, now at Headquarters Office, Department of Scientific and Industrial Research)

As interpreted in the field of building, operational research has involved the increased application of modern mathematical statistics to the study of methods of producing buildings and measuring their value in terms of efficiency, economy in production, satisfaction and economy in use. The application may be to the national economy or to any appropriate constituent part of it; the target to establish current levels of efficiency, costs of performance and their inherent variations, to define trends and identify their causes, to establish what are the requirements and possibilities, and to set in motion such adaptation or change as will ensure speedy and effective improvement.

The Post-War Situation

At the end of the second world war there was a considerable field for operational research in building as there was a great deficit of new buildings, and a huge volume of obsolescent or potentially obsolescent buildings. The building industry and the building materials industries had to be geared anew and there was a real urgency affecting both the domestic and export market for their products. Administrative and executive decisions of considerable magnitude and national importance required speedy and reliable settlement and were recurrent. In this atmosphere it is hardly surprising that an organised attempt was made to set up an operational research section to study building problems and that a systematic attempt was made to tackle the wide variety of technological and social problems which peace brought in its train. Operational research in building, of course, is not new. Work of this kind has been continuous since building research has been undertaken and the work carried out by the Building Research Station and other research organisations during the inter-war years and during the war, culminating in quantitative recommendations for strength of components, heat and sound insulation, protection against fire, etc., made it possible to judge, by logical and impartial methods, the value of the many new systems of house construction submitted to the housing departments with a view to post-war use. That work provided the "yard-stick" not only for the designer of buildings, but also for the operational research worker.

The essential difference between pre- and post-war activity is one of scope and emphasis. The scope has been widened to include all aspects of building design, construction, organisation, method and economics viewed not only from the point of view of the architect, engineer and builder but also from the point of view of the building owner and occupier. The emphasis has been altered to include a more specialised use of mathematical statistics in the study of building operations, user requirements, production processes and price movements, so that research has been taken into the everyday operations

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of industry in its ordinary functioning. This is of the greatest importance as conditions, skill and practice vary widely from site to site and from one operation to another.

The operational research problems in this field may be dictated by Government decisions, by foreseeable shortages of materials or of specific types of labour. More often, however, the real problems and obstacles to improved productivity and reduced costs have to be identified, and one of the first requirements is accurate first-hand information, backed by reliable current data, on the structure of the industry, its methods of organisation, methods of payment, the needs of the ultimate building owner and occupier, etc. This was not easily obtained by government research workers for whom the industry could feel no responsibility, but the response of industry was good and the degree of collaboration and active assistance provided was, in the circumstances, remarkable.

Systematic collection of data was thus made possible and subsequent analysis served to identify the operations which were most expensive in money and man-hours and which were, accordingly, selected for first treatment. In addition to indicating priorities, this study provided an invaluable background of information on the habits of the industry and on the nature of its development; it enabled the research staff to become acclimatised to the industrial environment and to understand its ways and its hazards; and it enabled research workers and industry to become acquainted and so to reach a degree of mutual trust and of active collaboration, without which there could be no progress in operational research.

The problem of increasing productivity and reducing costs in the building industry is a formidable one, owing particularly to the highly comparted structure of the industry. In the manufacturing industries the functions of design, estimating, layout of production, costing and marketing are all carried out within a single organisation. In the building industry the functions are separated, both in terms of personnel and of time, and this is inevitably a great disadvantage from the point of view of economy. In particular, the separation of the functions of design, production and costing must cause difficulties.

Structure and Scope of O. R. in Building

Out of the experience of these first formative years has grown a structure of operational research activity in building in Britain which is noteworthy at the least for its comprehensiveness. It embraces not only the immediate practical needs of the industry and government to provide sound buildings at low cost, but also the ultimate needs of the users of the buildings for efficient working and full living. Any one of the major research projects described below would provide material for a detailed discussion of operational research methods applied to industrial and social problems. The present paper seeks merely to outline briefly the scope of active operational research in building, to indicate the research approach to building and associated problems, and to illustrate the value of the work by reference to some of the results already achieved.

Productivity and Costs of Building

The importance, in the national interest, of the need to increase

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the productivity of the building industry and to lower the cost of building is well recognised.

The building industry, based on craft tradition, is not so formed that it can adapt itself speedily to major changes in techniques or organisation, and it is important that any systematic attempt to effect a marked improvement in output should proceed logically from a full knowledge of what the industry, as at present constituted, can achieve and what new techniques and tools it can readily absorb.

The research work moves from the study of the present performance of the industry to the definition of trends, measurement of changes, and identification of the major factors responsible for the change. Maintenance costs are studied to ensure that low first costs are not associated with high maintenance. Since reductions in labour cost can be dissipated in increased materials costs, it is necessary to study the productivity of building materials and components industries. Thus, those developments which are most likely to reduce real building costs should be clearly recognisable and it may be seen which industries are likely to be favoured most in the future by general trends in labour, capital, transport and raw material costs. For example, such trends may influence the relative competitive position of, say, cement products and clay products, or of different types of each. Such information gives guidance to the formulation of technical research programmes.

The general objectives on productivity and costs of building are:

i. *To identify the factors influencing productivity and to measure their effects.*

This involves sample surveys. A trial pilot survey of house-building was undertaken during 1949 in which analysis of the records for some 160 completed contracts gave a measure of the movement of productivity and costs during 1947-48 and of the influence of such factors as size of contract and bonus payments. It also showed that if we could raise the output on the worst 25 per cent. of sites to the average of the remaining 75 per cent., this alone would add nearly 10 per cent. to the national total of houses built each year.

A sample survey is now being made of the effect of the degree of sub-contracting on productivity in house-building in England and Wales during 1949 and early 1950. The power of the statistics of sampling has been recognised in a number of industries in U.S.A. but is still virtually unknown among industrial planners in Europe. It is well suited to the large, scattered and variable building industry.

ii. *To study the incidence of maintenance costs in building.*

Maintenance costs are clearly necessary for final comparisons of cost efficiency and efforts are being made to collect such information from existing records, classified, if possible, in terms of system of construction, components, materials, etc.

iii. *To study general trends in production of building materials and components.*

Studies of the general trends in cost and type of output in the industries manufacturing materials or components can be made from data generally available, or, in some cases, provided by the industry concerned, and from results obtained in (i) and (ii). Such data aid selection of the types of components on which further technical studies

of properties, production and use should be made. They should also afford general indications of the changes which the building industry may have to make in its techniques and organisation and so ensure a smooth and timely transition.

An essential part of the operational research work on costs and productivity has been the testing and demonstration of various solutions of building problems under full-scale building conditions. This has been done in the past by observing the process of building on sites of at least 50 houses each. The house types varied mainly in respect of external walls, party walls and partitions and a number of traditional "control" sites were included. The results showed that savings of up to 50 per cent. in labour requirements were possible and that, despite the short trial production runs, competitive house costs could be confidently assumed for some of the new systems. Analysis of the cost data revealed, however, that two-thirds of the total cost of houses are incurred in the internal components and finishings. As a result, an experiment has been designed which will involve about 400 houses for the purpose of examining new methods of constructing interiors and finishings of houses. As a result of this experiment it is hoped that it will be possible to indicate the most promising trends in house-building which are possible in the near future. The experiment includes a range of variations in the application of prefabrication to house-building. The selection of factory-made components, applying different basic principles in construction, has been so arranged that the results of the experiment can be synthesised to demonstrate the most promising type of house combining the components which offer the best contribution to increased efficiency.

Mechanisation in Building

The building industry has lagged behind most other industries in the use of mechanical aids and an intensive effort has been made during the past five years to stimulate development and production in this field. Priority was given to those operations which analysis showed to be most expensive in labour, e.g., excavating, concreting and materials handling. A number of new machines are now on the market wholly or partly as a result of the operational research effort. The concreting of house foundations, for example, can now be done for approximately half to two-thirds of the old cost and the output in cubic yards per man-hour can be increased threefold.

The current programme of research on mechanisation concentrates on the collection of basic information about the application of machinery with a view to stimulating development and production of new machines by industry rather than on the design and development of machines, though the latter is probably inevitable in some instances. The work involves the study of building operations in terms of their economic and physical requirements; the survey and testing of existing machines and prototype machines manufactured or developed both in this country and abroad; the specification of requirements for particular classes of machine; and the general study of the economic climate where changes in taxation, wage rates, etc., can materially affect the point at which it becomes economical to substitute capital for labour. In this field again due consideration is given to maintenance of equipment and to defects which lead to undue loss of working hours under normal site conditions.

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Building Materials and Components

It is generally agreed that the weak link in industrial research and development in Britain has, in many industries, been at the "pilot plant" stage which comes between laboratory investigations and commercial production. The Building Research Station has for many years progressively extended its studies in building and civil engineering to investigations on full-scale structures in the field. There has been a similar extension to what for convenience is called the full-scale "pilot plant" stage in the Station's work on materials and components. The operational research work in this field has been initially concerned with precast concrete manufacture, the study of methods of production and curing, and of control of quality and dimensional tolerances with the object of giving technical information which manufacturers can use in improving manufacturing processes. For example, breakages amounting to 15-20 per cent. of total production were being incurred in lightweight concrete blocks in their "green" state because the aggregate was too harsh. A series of tests was organised on a pilot plant using a variety of air-entraining agents and workability aids, as a result of which the production troubles have been remedied and the breakage rate reduced to nil. Tests are envisaged on the blocks produced by the new system to ensure that adequate control of quality is maintained in full production.

Another example arose from observation of the fact that three million tons of boiler ashes are produced annually at electric power stations in stoker-fired boilers. Although this material is basically a good concrete aggregate with valuable lightweight properties, it is contaminated at the source by the inclusion of excessive amounts of free carbon from unburnt fuel which are likely to cause trouble in concrete. Hence, although the material is well distributed over the country and cheap (because it is a waste product) only some half-million tons per annum are now used for making concrete blocks, often of inferior quality and mainly for use in non-load-bearing partitions. The British Electricity Authority spends large sums of money annually in disposing of the boiler ash waste. In an endeavour to enable the block-making and building industries to make full use of this source of cheap material for general purpose concrete blocks, and so to ease the supply particularly of lightweight aggregates, a full-scale pilot plant has been set up to study methods of processing power station boiler ash and of producing therefrom a satisfactory commercial building block. The results of this work give practical guidance to block-makers and others interested in setting up and running low capital cost production plants. In addition, it may enable usable fuel to be recovered by the power stations and can transform their hitherto expensive waste into a saleable product.

The cost of building materials is at present the major factor in total costs of house-building in Britain. But it is essential in any cost investigation, and particularly in the case of new products, to study not only the cost of the delivered component but also the overall cost of the component fixed or erected, and fully finished. Thus the final stage of operational research on materials and components is the

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study of their efficiency in use and of their contribution to increasing building productivity and reducing building costs.

Studies of User Requirements in Buildings

In its full sense the study of user requirements can be interpreted to cover a very large part of building research, but in its present context a more limited meaning is attached to it. Broadly, it covers the study of the influence of the design, construction, space distribution, and provision of services and equipment on the well-being of occupants and on the efficiency with which a building meets their needs, whether for work or leisure. At one end the work impinges on medical research and at the other end on the physical, material and structural properties of buildings. It is primarily concerned with studies which are both physical and sociological in nature and are concerned with the inter-relation between people and the buildings in which they live and work. This may best be illustrated by noting that investigations have been made on such subjects as domestic usage of hot water, on domestic tasks and the use and behaviour of kitchen equipment, on the way in which space is utilised in dwellings, on working conditions in offices as influenced by layout and equipment, and on the most efficient and economical ways of heating houses.

The work has involved surveys of several thousand households and planned experiments in which specially designed houses were built and their efficiency and cost of heating studied both in the occupied and unoccupied state. The heating experiment is being continued but it is already clear that additional first costs of heating installations in houses could well be justified by higher efficiency and lower running costs. It is also clear that the economic status of the tenants exercised a decisive effect on the results, e.g., when fuel bills were subsidised, the temperature difference between the insides of the houses and the outsides rose appreciably.

Work is also now being undertaken on the study of comfort conditions in kitchens and living rooms, including the effect of ceiling height on the physiological conditions and subjective reactions of the occupants; field investigations of domestic tasks with particular reference to the influence of planning and equipment; a survey of the performance of non-traditional houses and of the reaction of the users; studies of schools and factories to determine the physical conditions which are most favourable to the work carried on in them, e.g., heating, ventilating, lighting and noise and their influence on the work of the occupants.

General surveys of office conditions as affected by design, equipment and planning are projected.

For a more detailed account of completed operational research work and of the methods employed, readers are referred to National Building Studies: Special Reports Nos. 4, 8, 9, 10, 18 *and Bulletin No.* 11.

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ABSTRACTS

Terminal Problems in the Mechanised Transport of Timber.

ULF SUNDBERG.

Report of S.D.A. (Stockholm). **39-42.** 1949. *pp.* 5-24.

The weight and length of an assortment of timber being transported, and the size of load, are of profound importance in terminal operations—that is loading or unloading. Saw timber averages 5 m. in length and 150-200 kilograms in weight; an average truck load contains about 300 cu. ft. of timber—about 50 logs. Pulpwood may be in varying lengths between 2—8 m. or in standard lengths of 2, 3 or 4 m. Frequency distributions of different load volumes for various classes of timber are given.

The loading time for saw timber and pulpwood is found to consist of one part determined by the number of pieces, but independent of their size, and another part proportionate to that size. Preliminary studies indicate that the latter part is remarkably constant for all loading operations at any one mean length, provided the work is correctly organised and proper technical devices are applied. The important result of this relationship is that time and costs increase rapidly as mean volume declines. Two ways of avoiding this are indicated, viz., by combining small freight units in larger ones or by introducing mechanical handling on the moving line principle.

Problems affecting the jobs immediately preceding and succeeding loading and unloading are also considered. The paper goes on to consider the various loading machines used—cranes, loading winches, side loaders and log-hoists. The relative advantages and efficiency of these different methods are assessed on the basis of practical experience and limited time and work output studies, and suggestions are made of possible developments.

Intelligibility of Educational Broadcasts.

J. TRENAMAN (British Broadcasting Corporation).

Nature. **166.** *11th November,* 1950. *pp.* 814-815.

American investigators have attempted to produce formulae by which one could predict the intelligibility of written or spoken material by measuring such factors as difficulty of vocabulary, complexity of words, personal references and length of sentences. In 1949 Prof. P. E. and Mrs. Vernon undertook experiments to assess the effect of these and other qualities up to a total of 35 different factors. Objective qualities in the scripts were measured by taking sample passages of 500 words and counting the numbers of active verbs, prepositions, etc. Other qualities, such as lucidity, delivery, etc., were assessed on a rating given independently by a number of B.B.C. talks producers.

Intelligibility was assessed by having test papers completed by listeners who were asked to give ratings according to the ease of understanding the broadcast and their interest in it; they were also asked to reproduce in their own words the main points of the talk. The listeners used as subjects were soldiers in Home Commands listening as part of their normal educational activities; the full range of education and intelligence was covered.

In analysing the results of the intelligibility assessments a high correlation was found between intelligibility scores and education and intelligence level. After this, by far the most important factor affecting intelligibility was found to be interest in the content of the talk, particularly with lower education levels. So important is interest that many talks which bore all the marks of difficulty in style and construction but which dealt with an interesting topic were found to be better comprehended than simple talks on dull topics.

Further experiments are described which were carried out by Mr. Trenaman to determine the reaction of students to three science broadcasts. Three grades of student took part (sixth form grammar school, second year technical and non-vocational modern school). To test memory of content the students' reactions were assessed immediately after the broadcast and a week later. Striking differences in interest rating between these two assessments were found, particularly in the case of grammar school listeners, to a dramatised programme for secondary school children; many found it interesting at the time but in retrospect thought it childish or slow. On the average it was found again that the more interesting talks were more widely understood. But within the audience to any one broadcast the two factors were inversely at the three educational levels; thus grammar school students understood best but were least interested, while "modern" school students understood least and were most interested. In each broadcast, the educational group which most enjoyed the broadcast found it just, but only just, within its grasp, which points the importance of suiting the difficulty of the broadcast to its audience.

The Experiments on the Cornish Pilchard Fishery in 1947-8.

WILLIAM C. HODGSON and I D. RICHARDSON (Fisheries Laboratory, Lowestoft).

Ministry of Agriculture and Fisheries; Fishery Investigations. **17.** (*Ser. II.*) *No.* 2. 1949. 21 *pp.*

The aim of the experiments was to establish whether or not the landings of Cornish pilchards could be increased, so that the canning factories could receive adequate supplies to enable them to offset the loss of imports of canned pilchards from California.

The Cornish fishery was exploited by fairly small vessels using drift-nets, and the total catch could be increased in two ways, either by using more vessels or by increasing the efficiency of the existing vessels by using more efficient gear. Owing to a manpower shortage it was impossible to use more vessels, so it was decided to introduce the ring-net to Cornish waters.

For the ring-net to be successful, the fish must be located in dense shoals, since the net must be placed completely around the shoal so as to capture as many fish as possible in a single haul. The formation of the pilchard shoals at different times of the year was studied by means of the echo-sounder, which showed the depth at which the fish were swimming and whether or not they were swimming in dense masses.

Having found that the shoals were suitable for fishing with ring-nets, the next step was to design a suitable net which could be used

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to surround the pilchards without allowing them to be actually meshed, since the principle of the ring-net is to catch the fish alive.

The report contains a detailed specification of a pilchard ring-net, and describes in full the method of using it. There are also many illustrations showing the results of the echo-sounder investigations which threw light on the habits of the fish. It was shown practically that the ring-net boat could catch and bring to port two or three thousand stones of fish in about one hour, as compared with the drifter's catch of about four hundred stones taken in a whole night's fishing.

What do workers think?

SOCIAL SURVEYS LTD.

Future. **5.** *June/July*, 1950. *pp.* 15-19.

This is an example of a survey undertaken not to elicit facts but to determine people's feelings. Replies are essentially subjective and a pilot survey was first made to discover what questions could be asked with any hope of getting reliable answers; by this appears to be meant the questions about which the interviewees have any feelings to express. It was found that many questions important to management, and indeed to any citizen, such as the effect of world trade, costs of production, etc., on security of employment, meant virtually nothing to the workers on the factory floor; this is referred to as not the least significant finding of the survey but appears to be based only on the results of the limited, pilot survey.

The main survey is stated to be based on a sample "large enough to permit not only of the general findings being representative of the working population as a whole but also of being analysed by as many groupings of workers by age, sex, earnings, type of industry, size of firm and so on as would throw light on the influences which affect those attitudes." No other details of the sample or sampling technique are given.

The answers to the questions are set out in tabular form with analysis according to size of firm, whether private or nationalized and whether manufacturing, distributive or services. Reference is made to the effects of age, earnings, etc., but a detailed analysis on these lines is not given.

The general conclusion is drawn that workers behave very much as the typical voters behave at election time; that is, they are not so much for something as against something. In general there is a fair degree of contentment, almost of complacency. No particular causes for discontent are shown up and management can only improve the feeling of contentment by tackling the total environment of the worker.

Variations in Absenteeism during the Week: An Index of Employee Morale.

W. BALDAMUS and H. BEHREND (University of Birmingham).

Nature. **165.** *27th May*, 1950. *pp.* 831-2.

Attempts to measure morale by such indices as rates of labour turnover, absence or output are unsuccessful because they are always affected simultaneously by other factors such as earnings, working conditions and the appreciation of leisure. The authors suggest that these factors

do not vary from day to day, however, and that a comparison of absenteeism on different days of the week will give a measure of morale. This approach is based on the hypothesis that, owing to cumulative fatigue, the number of absentees in a factory should be expected to increase from Monday to Friday; if in reality the opposite happens, factors other than fatigue or working conditions (which do not change from day to day) must be involved, notably morale.

Five graphs are given showing the rate of absenteeism on each day of the week as the percentage of absenteeism on Friday, the figures being obtained from investigation at a number of factories. In one group of factories a smooth curve declining from Monday to Friday was obtained and this is stated to be consistently found for almost every week provided the sample is fairly homogeneous and not too small and provided there is a five-day week.

The hypothesis suggests that the steeper the slope from Monday to Friday the lower morale. This is stated to be confirmed by more detailed analysis of the material. For example, there is a very steep downward trend for foundry workers, while skilled tool-run workers show an almost horizontal line; less experienced workers show a steeper slope than those with longer service; women teachers, whose morale is expected to be high compared with factory workers, show higher absenteeism on Friday than on Monday.

It is found that the absenteeism of women, particularly married women, in factories shows less tendency to fall during the week than that of men; this is attributed to their lack of leisure at the week-end owing to housework. Nevertheless, it is claimed that this approach to the problem of employee morale is more objective and offers more scope for comparisons between firms, occupations and groups of workers than any method based on interviews and questionnaires.

Mathematical Problems in Operations Research.

P. M. MORSE (Massachusetts Inst. of Technology).

Bull. Am. Math. Soc. **54.** *No.* 7. *July,* 1948. *pp.* 602-621.

This paper is a lecture delivered to mathematicians with the object of drawing their attention to the opportunities for work of mathematical interest encountered in operational research problems. Specific examples of wartime operations research are considered and the mathematical processes involved in their solution are described.

The problems discussed are nearly all concerned with search and attack in naval or air operations. It is shown how the probability of contact can be built up; starting with consideration of probability contours for single-glimpse detection of an object on the surface of an ocean by eye or by radar, the effects of continuous observation, of movement of the observer and of the search pattern are considered in turn. Reference is next made to the tactics of attack and it is shown that problems arise of a similar nature to those discussed by von Neumann and Morgenstern in *Theory of Games.* Finally a strategic problem is considered dealing with the relation between the size of opposing forces and the casualty rates in combat of various types.

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In conclusion it is stated that the examples are intended to indicate that the mathematical problems encountered in operations research are not trivial and that while many important problems can be formulated in precise mathematical form a precise solution of all but the simplest of these is beyond the capabilities of mathematics at present.

Planungsforschung.

H. W. HOFMAN.

Schweizer Maschinenmarkt. No. 51. 1949. *pp.* 14-18, 49.

Operational research, its meaning and application, is discussed. It can be said that in industry operational research makes use of statistics to obtain a basis on which decisions can be made to improve the efficiency of the operation. Model research plays an important part. Psychological factors and influences which lie usually outside human control (i.e., climatic conditions) have to be taken into account. The fundamental law of conservation of matter and energy can be applied to money and tradition. The second law of thermodynamics in its statistical form rules order and disorder; that is, any ordered system can only be maintained by a certain amount of effort. A change occurring in one system will affect another. Static and dynamic equilibria govern the economic life of the country. By applying operational research to present day conditions a maximum output can be obtained with a minimum amount of working hours, energy and cost.

Planungsforschung.

PROF. H. SIEDENTOPF (Technischen Hochschule, Stuttgart).

Physikalische Blätter. **5.** *No.* 5. *May,* 1949. *pp.* 201-205.

The paper accepts the definition of operational research developed by Kittel and Goodeve. The idea of operational research was born during the battle of Britain in 1940 and was applied at that time to operations involved in the air defences. A thorough examination of all technical possibilities and in the training of personnel was necessary. This required a high degree of scientific knowledge which was provided by a small team of scientists attached to Fighter Command. Operational research guided by Blackett and Williams also played an important role in combating U-Boats. Post-war operational research has been applied to problems such as those arising from traffic control and transport of raw materials and goods. The objects of operational research include besides economic improvements the important problem of improving the basis for decisions regarding the application of science. Model research and the application of fundamental scientific laws to everyday problems are thought to be of value.

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PRODUCTIVITY MEASUREMENT IN BRITISH INDUSTRY

A Symposium of Papers by Authors with First-hand Experience of its Benefits

Published by the Anglo-American Council on Productivity, London, November, 1950

Reviewed by
DR. L. ROSTAS

MEASUREMENT of productivity can be carried out for at least two distinct purposes. The first major purpose is in connection with general economic analysis; light is thrown on past and future economic trends, on the relationship between national production and employment, occupational shifts, future output of the community, and so on. The second major purpose is that of serving as a tool of management, by illuminating the technical and organisational factors which contribute to increases or decreases in productivity and lead to variations between different plants and firms.

This excellent pamphlet is concerned with productivity measurement carried out primarily for the second purpose, by two research associations and a number of individual firms. It is a propaganda pamphlet in the best sense of the word, aiming at demonstrating the practicability of carrying out productivity measurements in British industry and illustrating the practical uses to which it is being put and could be put by industry. It is primarily addressed to the industrialist and practical businessman with the intention of promoting a more widespread application of these techniques in British industry. Research workers must look elsewhere to acquaint themselves with details of the measurement technique applied. (Such details are, in fact, available in three out of six cases dealt with in the paper, and we hope that the others will follow suit.) Nevertheless the pamphlet is of great interest for research workers as well.

Two of the papers refer to the work of the co-operative research associations: (i) to the surveys by the Boot and Shoe Research Association (their short paper in this volume is an especially lucid and comprehensive account), and (ii) to the surveys of the Shirley Institute. The latter are reviewed by a textile manufacturer (Mr. H. Moss, of Thos. Taylor & Bros. Ltd., Wigan), who is making practical use of this work. Two of the papers describe the surveys of multi-plant firms, such as that of Courtaulds in the field of rayon (contributed by H. L. Bingham) and of an unnamed firm that controls some 30 factories of varying sizes (contributed by "Pelagius"). Two papers describe the measurement work carried out within particular plants in two big firms, Joseph Lucas Ltd., making a wide range of motor-car accessories, and United Steel Cos. Ltd. (contributed by Mr. A. W. Swan). Between them these studies cover a fairly wide range of products from rayon, a fairly homogeneous product, to a product mix of motor-car accessories and they cover all the three main aspects of measurement, namely, time studies, inter-firm comparisons and international comparisons.

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It appears that all the firms are interested in productivity changes over time as an indicator of progress made and of performance. The two multi-plant firms are also making inter-plant comparisons and its importance is also emphasised in the steel paper, though "Pelagius" observes that in his opinion inter-factory comparisons are of less importance than time comparisons in one factory owing to difficulties of interpretation of differences. He also thinks that full value can be derived from inter-firm comparisons, outside the firm concerned, only when the exchange of information is arranged privately between the participating firms, a view which is flatly contradicted by the work of the research associations whose notable contributions precisely are in the field of inter-firm comparisons. One of the multi-plant firms, Courtaulds, also makes use of international comparisons based on the records of their subsidiary and associated companies in five countries producing broadly identical products.

There is a surprising amount of common ground in these pages. All relate to measurement of labour productivity and the basic concept used is mostly output per man-hour or its reciprocal, i.e., man-hours needed per unit of output. Strictly speaking, it is, of course, the relative (and not the absolute) level of output per man-hour which is identified with productivity, a comparison of the actual level with a past level or the actual level in one plant with the level in other units in the same firm or in the industry. Again, the past level can be either the level at a given date or the level experienced over a lengthier period; the latter is usually called a standard period. In some cases the basis of comparison is not the actual experience at a past date but some other criterion, e.g., the best-known world practice. Thus the paper contributed by J. Lucas Ltd. distinguishes a so-called productivity index, which is the ratio of estimated "objective standard hours" per unit to actual hours per unit. They regard this index as a resultant of two further indexes, one of which relates current standard hours per unit to actual hours per unit, the other relates objective standard hours per unit to current standard hours per unit. They call the first an index of labour utilisation, the latter the current technical index. The latter mentioned index can be expected to be unchanged over a fairly long period so that only the movements in the other two indexes (either of which can be regarded as a productivity index) are of real importance in the short run.

Output is measured in all cases in physical units. On the all-important technical problem of comparing the output of plants producing either variations of one product or a variety of different products, the papers only provide broad hints. It would appear that the most frequently used conversion factor is the labour content of the various products measured either by past experience or on basis of time studies. By the use of such conversion factors output can be expressed in terms of what might be called a standard product, and thus comparisons can be made between two periods in spite of changes in the product make up or between the productivity of different products made in the same firm. The methods applied also make it possible to make allowances for changes in specification of the product, for work in progress, and so on.

Input is measured in terms of man-hours and includes indirect labour as well as direct labour. In the system described by "Pelagius"

covering the whole activity of a plant, this is automatic in the sense that all man-hours worked which appear in the cost accounts are recorded and allocated for productivity purposes as well. In cases where selected products or selected processes only are covered by the productivity surveys some rough and ready allocation is made of indirect labour by methods which again are not disclosed.

On the face of it, the productivity index explained in the steel study differs from the others as it is, strictly speaking, an index of machine activity measuring tons produced per hour of running the machine and not per man-hour. Stoppages during the hour are conveniently dealt with by adjusting output. This type of measurement is nevertheless an equally good indicator of labour productivity also is nevertheless an equally good indicator of labour productivity in the short run if the manning of the machine remains unchanged.

The computation of relative productivity levels is regarded in all cases as only the first step, to be followed by an analysis of the reasons for changes and variations. Nevertheless it is emphasised in many of the papers that a knowledge of relative productivity levels is by itself of great significance.

All the papers throw an interesting light on the way in which the information derived from the surveys is utilised. On the industry level, broadly speaking, this utilisation can take two forms: (i) for controlling operations, (ii) for determining long-term managerial policy and planning. It is interesting to note that most of the surveys seem to serve rather the latter than the former purpose. (These surveys are also of interest in general economic analysis.) On the other hand, the shift report described in the steel study is the typical productivity survey, serving purely for operational control, while the method used by J. Lucas Ltd. appears to be of some use at least for both purposes.

One other interesting point emerges from the papers, namely, that productivity measurement is not replacing but is supplementing other managerial techniques, such as costing, works measurement, etc. "Pelagius's" system is an extension of the costing system revealing information which cannot be available from cost accounts.

Another example is the use made of work measurement results in operating the productivity surveys of J. Lucas Ltd. Also, both Courtaulds and the cotton textiles study describe how surveys of productivity measurement, reflecting the general efficiency in the utilisation of labour, are supplemented by a comparative analysis of labour utilisation in individual jobs based on work measurement methods.

The Anglo-American Productivity Council should be congratulated for producing this pamphlet. It is to be hoped that the utilisation of these techniques will spread widely in British industry and that we will be acquainted in time with other methods additional to those applied by the pioneer organisations who have contributed to this booklet.

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CORRESPONDENCE

Sir,—Before I return to Australia may I add my contribution to the discussion on the nature of operational research?

First: I would suggest that in defining it, the word "research" should not be qualified as "scientific". Use of the phrase "scientific research" suggest that there is, and should be, unscientific research; I cannot agree to this.

Second: I regard it as inconvenient to classify completed work according to the attitude to it of one's chief executive. This could mean that a category would alter over lunch, and the task of indexing the work might become quite impossible. It is true that executive attitude is important in getting operational research carried out, and in getting value from the research, but it has nothing to do with the nature of operational research.

May I suggest that operational research is to be distinguished within the general field of research by the fact that it includes all three of the following characteristics:

1. Operational Research is observational. This means that it includes the assembly of data. An investigation which consists of prediction from basic hypotheses is not operational research.

2. Operational Research aims at determining the behaviour of a system in relation to its environment, or at determining the response of the system and changes in the environment. At one extreme, operational research must go further than presentation of tables of statistics, it must aim to produce some order by discovering significant general characteristics. At the other extreme, operational research is not concerned with explaining why the system behaves as it does, nor with deriding fundamental laws which would explain its behaviour. The operational characteristic of the research ends when the behaviour has been determined.

3. Operational Research has the characteristic that it deals with systems and organisations which are set up, or exist, for some purposes other than the research, and that the research project must not interfere unduly with the fulfilment of these other purposes.

I do not limit systems and organisations to social systems and social organisations. I can visualise operational research in such diverse fields as medicine, engineering, economics and biology as well as in social fields. In all these fields the common aims and circumstances determined by 1, 2 and 3 lead to a considerable similarity in general method or approach; this is the discipline of operational research.

Yours faithfully,

I.C.I.A.N.Z. Ltd.,
London.

J. R. BAINBRIDGE.

A correspondent writes:

"I feel convinced that only the 'truth' can keep us free, and that sequential inference and operational research . . . are the best safeguards against corrupted judgment, infiltration and intimidation . . . One of my difficulties has been to get accountants to think in terms of patterns and significance, rather than of meticulous accuracy and procedure."

This might be a good line to take with the Inland Revenue authorities.

OPERATIONAL RESEARCH CLUB

THE third meeting of the present session was held on January 23rd, when Professor Waddington and Dr. Rendel read papers on Operational Research in Livestock Breeding. Professor Waddington dealt with the general organisation of the work and pointed out that it came somewhere between the practical method of setting up breeding farms and the theoretical approach pure and simple. One of the difficulties was to decide who was the executive for whose benefit the information was being provided. The Ministry of Agriculture, the artificial insemination stations and the farmers were all in part the executives concerned.

Another problem was deciding what exactly it was required to do, as for example whether it was better to aim at an increased yield of milk per year or per life of beast.

Dr. Rendel dealt with some of the results of the researches concerned with dairy cattle. He showed how it was clear that for the five main breeds the necessity was to level up to the best within each breed which was very far above the average. Most breeders could not achieve more than half the improvement in yield theoretically possible from selective breeding. A general conclusion, which excited considerable discussion, was drawn that improvements could more easily come from better herd management than from improved breeding. Dr. Norman Wright was in the chair.

At the fourth meeting on February 21st a paper was read by Dr. N. Wright and Mr. M. Compton describing the use of surveys for operational research at the Ministry of Food. Two types of survey were defined, those to determine general consumption levels and surveys of particular commodities or groups of commodities. The biggest general survey was the National Food Survey started during the war, to see whether the Ministry's target was being generally met and whether there were any vulnerable groups in the community which were not getting enough to eat. The more specific surveys were usually concerned with the possibilities of taking particular foods off the ration; in this category were the ration off-take surveys and the consumer demand surveys. The objects of these surveys were primarily to provide data for administrative action, but much information of fundamental physiological interest had also been obtained. Sir Jack Drummond was in the chair.

ERRATA.

In Vol. I No. 4. December, 1950:

Table III. p. 61. Col. I for 1943 read 1948.
Under Male first col. for 191 read 101.
fourth col. for 34 read 3+.
Under Female (fourth col. for 3 read 3+.

Table IV. p. 63. Under Cost line 1 (enumerated) for £198. 11. 7½.
read £153. 19. 1½.
Last col. line 2 (checking) for 77% read 19%.

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OPERATIONAL RESEARCH QUARTERLY

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A PROPOSED DEFINITION OF OPERATIONS RESEARCH

by

ROBERT GOODELL BROWN (WILLOW RUN RESEARCH CENTER)

Lack of space precludes us from printing Mr. Brown's paper in full. We therefore asked Dr. T. E. EASTERFIELD *to summarise and review it.*

MR. BROWN'S paper is an attempt to define and to show the essence of operations research. He sums his paper up in the following way:

"Operations Research is the quantitative study of the operations of a complex organisation and the prediction of the effects of changes in conditions for the guidance of executives in obtaining the maximum effectiveness from available resources.

A complex organisation has a specific purpose which can be measured quantitatively. Toward this purpose there is a large number of similar operations which contain both systematic and random elements.

The available resources include men, money, materials and equipment as well as forces not under control of the organisation, such as competition and time limits. The resources are limited.

The effectiveness of the operation is measured by such quantities as the ratio of payoff to effort, the probability of the occurrence of a favourable event, the ratio of present performance to past performance or the time rate of output.

The quantitative study of the operation is made by statistical analyses of operational data to predict the outcome of similar operations. In addition, experiment and theoretical deductions make it possible to predict the outcome under changed conditions and thus to design the operation to achieve a specified effectiveness.

Finally, the operations analyst has freedom to initiate and solve quantitative problems, but works in close conjunction with a high-level executive who must make the actual decisions based on the

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recommendation of the analyst and the non-quantitative features of the situation."

He himself states that he considers operations research differs in some respects from operational research as understood in Great Britain; but he does not make clear what he believes to be the difference. If one accepts my own definition of operational research, namely: "Operational research is scientific research into the operations of a going concern, carried out for and in collaboration with the executives of that concern," it would appear that Operations research is a restricted field within operational research. As I shall try to show in this review, the restriction appears to be unnecessary and hampering, and based on a limited view of what constitutes science. But it is possible that Brown is describing what is rather than what ought to be; and certainly there is enough that is of value and more that is thought-stimulating in this paper to make it worth serious criticism.

The author considers operations research to be a science, apparently because, as he states, "scientists engaged in operations research during the war were struck by two simple but surprising facts:

(1) large bodies of men and equipment carrying out complex operations behave in a regular manner; so that the outcome of such operations can be predicted to a degree not foreseen by most natural scientists;

(2) the lack of understanding of the scientific approach to a problem and the lack of awareness that scientific methods can help solve the operational problems on the part of most governmental, military and industrial executives is likewise astonishing (as well as depressing) to natural scientists."

It should be noted that these two facts form an odd contrast. If natural scientists could not foresee that large bodies of men and equipment would behave with regularity, it is hardly reasonable to be astonished or depressed that executives saw little use in the scientific approach; but in fact almost all action in large concerns—businesses, governments, armies—has been based on the implicit realisation that over a large body of people regularities of behaviour may be expected. Brown's conjecture later in the paper that the regularities are largely due to the use of common equipment therefore seems unnecessary and unjustifiable.

In fact, in his exposition of the subject, Brown makes no use of the idea that operations research is a science in its own right, rather than an application of the scientific method to a new field and in a new relation to the executive; and for this reason, the point does not need further discussion. The fact, however, that he bases operations research almost exclusively on the regularities of large organisations, coupled with the view that only quantitative study merits the description "scientific," has to my mind led him strongly to over-emphasise the role of statistics.

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In analysing his definition he treats five special features of it. First, that the organisation studied should be complex. This is, I think, important. Because a simple organisation can probably be run by its executives as efficiently without as with scientific analysis, it is a misuse of scientific effort to try to do operational research on one single small organisation; though it may be noted that it may be valuable for a trade or research association or similar body to carry out such research on a number of small firms, so as to find new and unsuspected regularities, or to confirm or disprove the existence of regularities commonly believed to obtain.

Second, that the study should be in terms of available resources. My first reaction to this was that it was a truism; any activity must be carried out within its own limitations. But on second thoughts it seems that this may be the sort of truism that is fruitful because it is so often disregarded. Many operational research studies have begun with an investigation of what in fact were the available resources and which of them were the limiting factors; and this point is probably worth emphasising.

Third, that performance must be measurable in quantitative terms. Again this seems to me to be an aspect of a valuable part of operational research, but too restrictive if it is to be regarded as essential. Nevertheless, if the paper were modified to suggest that a valuable part of operational research was the construction of performance ratios of the real measure of success at any level to the important limiting factors, I should agree heartily. At this point, Brown very wisely brings out the fact that a valuable part of operations research may be the analysis of the real aims of the organisation, and he himself admits that this may not be quantitative by remarking that it is frequently a semantic study. One acts efficiently only by a coincidence unless one knows what one is trying to do; but this truism again is neglected by most people, scientists not excepted, unless they force members to analyse their aims. As he points out, careful analysis of the real purpose of the organisation may in fact save further investigation or discussion.

Fourth, that the study is wholly quantitative. He bases this feature on the belief that all scientific activity is quantitative, a view which would rule out a great deal of geology, biology, psychology and the social sciences. It seems a quite unnecessary restriction since in many problems, e.g. of administration, structural or functional analyses rather than quantitative analyses are the proper tools. Having decided that the analysis must be quantitative, he then is naturally led to the view that statistics is the prime basis of all operations research, since only thus can the fluctuations in numerical quantities in a complex organisation be eliminated. Though it is probably the most used single tool, statistics has played little or no part in many valuable pieces of operational research.

At this point, Brown gives a succinct analysis of what the scientific method is, in the usual terms of the cycle of data collection, data

analysis, formation of and deductions from hypotheses, the cycle being completed by the search for fresh facts to confirm or disprove these deductions. He wisely stresses the need for intuition, creative ability and structural insight at the third phase of this process.

Finally, operations research is for executives. It is for the guidance of executives and, as he stresses, such guidance can be given only by someone in close personal touch with the executive, so that he can find out what the executive is really trying to do, what sort of problems he wishes to solve and when an answer is required. Though it is hardly true that every executive's decision must be taken quickly, it must be taken by some date line and will be taken whether the adviser has given his advice or not. Moreover, Brown might have gone further and pointed out that close contact with the executives may also reveal the sort of problem that may become urgent in, say, a year's time and may be worth trying to solve now in anticipation.

Thus, to sum up, Brown gives a good picture of the use of scientific method to help the executive of a complex organisation in taking his decisions, but restricts the field of activity by insisting that such work can be done only where the problem can be reduced to numerical terms, in particular by there being a numerical measure of success. Experience in this country suggests that the restriction is unnecessary.

O.R. Club Meetings

About 100 members and guests attended the Club's meeting to discuss Productivity Measurement under the chairmanship of Sir Henry Tizard, F.R.S., on March 21st. A full report appeared in "Engineering" for May 11th.

On June 13th papers were read by L. H. C. Tippett, A. W. Swan and M. G. Bennett on the relationship between O.R. and the executive in small, large and nationalised concerns respectively. Discussion centred mainly on the avoidance of a clash of personalities between the executive and the O.R. worker. The situation was often easiest when the O.R. worker had no established position in the hierarchy plus enjoying friendly access to executive and workers at all levels.

Invitation

Professor P. M. Morse, of the Massachusetts Institute of Technology, has extended an invitation to all O.R. Club members to visit him "when they come to Cambridge, Massachusetts."

Change of Address

A new editorial address and telephone number appear on the inside front cover of this issue.

Postage to Overseas Subscribers

Overseas subscribers to this Quarterly will in future receive their copies by surface mail instead of by airmail, except where a specific request is received. In such cases a supplementary fee of five shillings per year (one shilling and threepence for single copies) will be payable. It is regretted that rising printing costs make this step necessary.

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OPERATIONAL RESEARCH SCIENTISTS

by

H. A. SARGEAUNT

THERE is no tradition for teaching operational research, and what is written here is an individual view; but it is the result of an experience that extends over nearly eight years—of being taught and of teaching. These are my credentials.

One needs in writing to decide whom one is addressing. This article is addressed to those of you who are already experienced in operational research, but who wish to improve the group which you are either leading or in which you are influential. It is taken for granted that you already have a way by which you interest outside people in your work, a way in which you train the young entry, and a way by which you improve your more experienced scientists. My purpose is to suggest how you should study these ways so as to improve certain aspects which were important in my own work and which, judging from talks with others, are important in yours too.

I was for a time head of the Army Operational Research Group which had a total of about sixty scientists, including scientific assistants. To begin with, I believed it sufficient to select one's personnel carefully and that their training was a minor matter. I no longer agree with that.

Firstly, several of those chosen for their statistical knowledge failed to grow into good operational research workers. Secondly, those who had not a full scientific training, or who were not obtaining one, proved of little use in spite of the keenness for which they had been chosen. Thirdly, several people, written off as dull, changed quite surprisingly when teamed with a go-ahead group; they developed a nose for problems. And fourthly, there was a vague uneasiness in the air at the habit of unrealised humbug that many older operational research workers were thought to have developed. I argued that if their good work was to be retained and their nonsense eliminated, a refresher course must be provided. For myself, any scheme of training that cannot deal with these four points is inadequate, and though it is unwise to make too much use of personal troubles, yet because I believe that others have them too, they will be included in the more formal treatment of my subject.

Three main aspects are normally stressed in teaching classical science, and these will be taken in turn as far as operational research is concerned.

These are:

(a) An adequate skill;
(b) The acquisition of a scientific spirit and tradition;
(c) (more difficult to express) the creation of a character and

behaviour suitable to members of a scientific group or institution.

We are at present far from such standards in operational research but they clarify the object of the more controversial steps I shall advise.

An Adequate Skill

To begin with, as to the adequate skills that should be taught in operational research, these are of two types: the skill to choose the form of analysis most useful to the executive one is trying to help, and the skill to collect the facts and to analyse them in the chosen form.

As to the first type, I have grown to disagree with present practice in its stress on the teaching of statistical methods, not because I would not use statistical analysis, that would be fantastic, but because it is only a part of operational research, and good statisticians do not necessarily make good operational scientists. The object of operational research is to help those in executive control to come to wiser and better decisions. That is basic, but it implies that the control of events can be improved by a knowledge of the facts collected by science. But how? The answer is not obvious, and yet without a thorough grounding in this subject no operational scientist is fully equipped. This matter is so important I will allow myself to digress. One cannot discuss training unless one knows what one is training for; and it is this I wish to clarify and rescue from the doctrine that at present engulfs it.

Most of us have seen the careful worker who has laboriously used statistical analysis, has tested and amplified his figures, only to discover that the leader to whom they were presented has already decided and passed to new problems. Events are often so transient that decisions can only be made on a quick appreciation, an overall look by an experienced executive. He sees the field of events and decides, and what he wants is to visualise as much as he can in one sweep of his mind. Thus what he demands is something quickly available that will enlarge and focus his vision. To provide a subtle and intricate statistical analysis for part of the subject will be a hindrance to such a man because it will break and disturb the wider sweep of his judgment that must cover the whole field. And this a scientist must be taught.

There is a strong classical tradition that science is a way of describing and presenting events. It is the teaching of this tradition that should be amplified, remembering that the object is to include only such a degree of detail as will help the leader to come to wise decisions. In such cases the skill of the scientist lies in the development of quick ways of collecting facts, and in simple ways of presenting them, such as maps of events or models. Perhaps the reason why the teaching of statistical induction has been so overstressed since the war is because there have been many demanding planners who have been acting in limited and special fields. Statistical induction is

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ideally suited to meet these limited needs, but in the wider actions of the world more is required, as a scientist must learn.

For example, in the early days of battle in Normandy during the last war, the sway of events was so changing and transient that decisions had to be made quickly. Commanders wished for a map of events, of relevant events. So too, when an exporter is trying to fit into an active market, he wishes for an immediate knowledge of relevant facts. In both cases, it is the invention of techniques for collecting the data that is the problem. In neither case were really satisfactory techniques evolved. Classical scientists have developed the electron microscope to study minute events; equally operational scientists must be taught to invent techniques for quickly collecting knowledge about widely scattered events.

I have stressed this fact, of leaders under certain circumstances taking quick decisions, not to decry the teaching of statistical analysis —I repeat, that would be fantastic—but to show that in many cases statistical analysis is totally irrelevant, is indeed harmful, and that what must first be taught the recruit is how to distinguish when and where each form of analysis is relevant. The way in which the recruit should be taught is to train him to put himself into the frame of mind of the leader taking the decision. He must be taught to develop a controlled imagination as to what it means to be in executive power; how sometimes it is immediate action that counts; sometimes (as in planning a future large scale operation in peace or war where much of the future cannot be known) it is the asking of the right questions; how sometimes it is the patterns of behaviour and their statistics; and so on. That is the basis of an operational scientist's education in skill; and without this, the rest is futile. The ultimate modes by which men control events are several; and the scientist must know which is being used at any given moment, and how the modes of analysis of science fit into them. And that is fundamental.

Once the scientist is sure of what mode of control the leader is using, and the best corresponding mode of scientific analysis, then he must decide what facts to collect. This is easy to teach because it is akin to the ordinary techniques of science. If one is studying a pattern of events, then the collecting of data for statistical analysis is obviously suitable—a Trades Union Official is quite ready to be helped by a Gallup Poll where he would ignore subtle arguments. Or, by contrast, a business executive planning a new development is ready enough to listen to facts about whether he is asking the right questions. Here again the teaching of what are the best data to collect in such a case is not hard. A scientist who has been well trained in a critical laboratory, where the purpose of every experiment has been argued to the full before it has been undertaken, is already well versed in this technique of collecting facts to help decide if he is asking the right questions. So too with other modes of analysis.

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Here then is my explanation of why an operational research worker should be a good ordinary scientist. These ordinary skills are essential to him. Those who are not or cannot be made good scientists are not needed.

The Scientific Spirit

Now for the second aspect of classical training: the acquisition of the scientific spirit and tradition. In the ordinary way of science, this is attained by working under a good scientist whose outlook and presence pervade the whole group. The same should happen, and on the whole does, in operational research, but it should do so in a rather special manner because operational research demands an extension of the normal spirit of science.

I am very obstinate on this point. I have worked under or with many successful men in this field, have studied many more, and am convinced that at their best they add a new quality to organised science. I would define this quality as a higher degree of scientific sensibility. Let me explain.

The virtues of traditional science have been derived from those qualities which the great scientists of the past have displayed: Galileo, Newton, Harvey, Faraday and so on. No one term covers all these qualities, but perhaps the term "scientific elegance" gathers together such ideas as lucidity, brevity, penetration, generality and so on. At any rate, I shall use it here to signifify the integration of qualities that classical science has given us, those qualities for which high class scientists are chosen and paid. My claim is that operational research should teach one other virtue besides scientific elegance, namely scientific sensibility.

I would amplify my definition of this quality as that subtle awareness that can feel and experience events in such a way that potential scientific problems are quickly sensed. It is an awareness, so one may imagine, that nobody but a scientist will possess to the same degree, an awareness that can see food for scientific thought in the problems and decisions of other people. It is interested in actions outside science, and yet is interested in these actions in terms of scientific possibilities. If it were an easy quality many would possess it. I claim it is a hard quality to acquire. I would say that it has been exemplified by such workers as Sir Charles Goodeve, Professor Blackett and Professor Bernal. Scientific sensibility is a quality of thought and experience, and it is something that should be added to the scientific training and spirit of operational research. It is something for which operational research workers should be chosen, paid and promoted, and for which they should be encouraged and trained. I will not pretend that I think this quality of scientific sensibility easy to demonstrate. Many classical scientists certainly possessed it, but it was not important for science in its development during the 17th and 18th Centuries. It was more appreciated, especially in biology,

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during the 19th Century, but I do not think even here scientists were advanced in their profession because of it. As I believe this quality is best encouraged in a varied group, that is the reason why nowadays I would team my recruit with such people.

Character and Behaviour

Lastly, to the third aspect of training: the creation of a character and behaviour suited to the members of a scientific group or institution. This may be thought an unnecessary frill, but it is essential, in a widened form, for operational research, or indeed for any scientific adviser. Living so much amongst other scientists, we are apt to forget how we appear to others when we attempt to sit at the same committee or argue in public with them. In the thrust and parry of taking decisions and in collaboration with others, a first class practical scientist will appear passable; any other scientist will seem inadequate. This is a personal judgment with which many scientists will perhaps disagree, but before accepting their verdict, judge dispassionately or ask an unbiassed spectator. I do not think such tests will contradict my assertion.

If true, it is not a criticism of the intrinsic merit of scientists, but of their training. A well trained diplomat will perform his public functions far more adequately than his intrinsic capabilities warrant. His outward form and behaviour have been schooled, so that whatever wisdom he has to impart is fully effective, and his folly is hidden. Our present public tradition for behaviour amongst scientists is based on the standards of behaviour in our learned societies. Such behaviour is inadequate for the wider world to realise the qualities of scientists in action. I do not know what is to be done, except to study both those who make, and those who fail to make at least some success of it either by fitting in to an organisation or by their personal presence and behaviour.

As an example of fitting into the mechanics of an organisation I once worked for an adviser who, in the written word and minute, successfully dovetailed scientific advice into official policy. Under his direction, a scientific memorandum was broken up into its component parts and distributed where the parts could best be used. He was a professional in this respect, and his technique worthy of study in training operational research scientists how to integrate themselves into an already working modern administrative machine.

But it is in one's personal behaviour that the greatest trouble comes. Those scientists who impress the layman are apt to strike their fellow scientists as either windbags or else political mountebanks, never ceasing to compromise; while those scientists who impress their fellow workers are apt to strike the layman as either ineffectual, or else as having some inner hidden motive behind their cautious vacillations. If I exaggerate, I do not exaggerate greatly. I would find it hard to point to more than a very few scientists in higher posts who strike me as having an automatic trained behaviour and speech that reflected the true worth of their undoubted ability. To every

one such I could name, I could name ten who failed to do themselves justice.

It may be claimed that this is not pertinent to operational research. But if leaders and executives are to be assisted by scientific knowledge, it is important that an etiquette and outward form of behaviour should be evolved that reflect the qualities of what scientists can do and their worth. I can see no short cut to attain this except by trial and error; holding firmly to what succeeds and discarding what fails. But this presupposes an intelligent school of thought where such subjects are raised, and where people's behaviour can be wisely and generously, but also critically, discussed. The poverty of the present position can be seen by the persistent and apparently seriously given advice that an operational research worker should be a good social mixer or at least a drinker of beer. Such a gift might perhaps be a minor adjunct, but given as major advice it is a declaration of bankruptcy. It is to acknowledge that one's formal behaviour is inadequate. And yet I fear it is the truth. Operational science needs to decide what it should discard, and to perform such discards ruthlessly.

On Recruiting Staff

So much for the formal aspects of training. Naturally each leader in operational science will have his own solution of how these principles should be translated into practice. My own advice, for what it is worth, is the following.

For those about to increase their staff with recruits who have never been in operational research, only choose already qualified scientists, or those willing and capable of quickly becoming so. Having chosen your man, team him with a capable and varied group who are used to working together. (My ideal group, ignoring time and seriousness, would be Darwin for field work and to collect the facts—but not to write the reports, he would be too slow; Karl Pearson for statistics because of his flexible mind; Faraday to ask the right questions and for any experimental verifications; and Bertrand Russell for the logical appraisal of what was concluded, and to provide that degree of irritation and stimulus without which no group can remain urgent and vital.) Where convenient, let your recruit be present when you are discussing problems with the executive or leader whom you are advising and for whom the operational research is ultimately being done. After a time of such team-work and coaching, your recruit should be allowed out on his own for minor problems.

For those already in operational research who wish to improve, my practical advice is to form a study-group with one of its purposes to criticise operational research adversely. Try to get as guests, non-scientists, and scientists other than operational research workers. Spend more than half your time in discussing those people and those studies that have failed. Grant privileged comment. Be ruthless especially to those present. Say bluntly where you detect a

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fraud. Discuss what operational research to-day does *not* want; decide what is to be rejected.

My advice to those not yet in operational research, who wish to learn something of it, is to go to formal lectures that are primarily based on statistics—in spite of what I have said. I deplore the present excessive accent on statistics in operational research, but some firm peg is needed on which to hang one's attendance. The best peg is practical experience; but where impossible, use a mature technique such as statistics. Listen with the resolve to widen out later, which can best be done by attending the study-groups I have suggested above, or by attaching oneself for holiday periods to active workers.

Lastly, nothing can take the place of continuous practice and enthusiasm in operational research itself, just as for a higher degree in any scientific field, nothing can take the place of practice and enthusiasm in that particular science.

I started by stating that this article would express my individual views. It has certainly been individual, and perhaps provocative as well. I shall be content if I have demonstrated to others the reasons for my more debatable instructions: that statistical analysis should not be over-stressed, that only qualified scientists or those about to become so should be chosen, that they should be teamed with a variously minded group, and that Operational Research should decide now what it is going to reject.

ABSTRACTS

A Further Analysis of the Returns of the E.R.A. Sampling-Survey of Domestic Consumers.

P. SCHILLER and W. A. PRIDMORE (British Electricity Authority). *B.E.A. Utilisation Research Report No.* 4; 17 *pp.*

In 1946, the Electrical Research Association (E.R.A.) organised a sampling-survey of the domestic consumers of about 60 electricity supply authorities, whose consumers represented one-third of the total in Great Britain. Some 50,000 records were obtained, giving details of the appliances installed, premises, households, etc. After nationalisation of the electricity supply industry, the matter was pursued by the British Electricity Authority, and the report contains the results of a punched-card analysis by size-of-dwelling and other classifications.

Of particular interest is the application of the simultaneous-equations technique to calculating, from appliance records and annual consumptions of individual consumers, the consumption attributable to given appliances, e.g. cookers, water-heaters, fires, etc., with various types of consumer. In further development of this method it is possible to estimate, for instance, what proportion of the total consumption of the domestic consumers of the supply industry was used, year by year, for space-heating purposes, etc.

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The Application of Statistical Methods to the Analysis of Service Performance Data.

J. W. BONEBAKKER

Trans. N.E. Coast Inst. Engineers and Shipbuilders. **67,** *Pt.* 66, 277-286, *April,* 1951.

Two main points are advocated:

1. Improvement of ways and means for collecting reliable and acurate records of engine output, propeller revolutions and ship's speed through the water, under varying service conditions.
2. The introduction of statistical methods to the analysis of such data, in order to limit their amount and to improve the reliability and accuracy of the information deduced from them.

Ultimately, the correct relation between power, revolutions, speed and apparent slip is to be ascertained for any set of specific external conditions likely to be met in service. If this aim is to be achieved without recourse to model experiments, it would take a ship's lifetime to collect the mass of basic information required for computing a "generalized power diagram." Modern statistical methods enable us to limit the amount of this basic information, and to reduce the set of curves of the generalized power diagram to a single straight line, even if more factors than those mentioned above are brought into the picture (for instance, ship's draught).

Service performance data of three ships are analysed to and sample calculations are given. Reference is made to screw propulsion theory and first principles of mathematical statistics in appendices.

Yearly Surveys of Consumer Finances.

Federal Reserve Bulletin (of the Federal Reserve System of the U.S.A.), **32 et seq.**

A series of sample surveys of consumer finances has been carried out annually since 1946 on behalf of the Federal Reserve System of the United States. They were undertaken to investigate the post-war pattern of spending and in particular the use that would be made of the liquid assets accumulated during the war, in view of the importance of the effect of these factors upon the stability of the United States economy.

The data have been collected directly by personal interview from a random sample of the entire population of the United States, excluding only certain special classes such as members of the armed forces. Such interviews are expensive, and a feature of the surveys has been careful design, using modern methods such as multi-stage sampling and optimal allocation between income groups. In this way it has been possible to secure the desired precision using only 3,000-3,500 interviews. Since no satisfactory lists of the population exist in the United States, area sampling was used, that is, a random sample of areas was picked out and the interviews chosen from these areas.

By this method of direct enquiry in the field it has been possible to secure much valuable information on saving and spending which would be unobtainable from any other source.

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On Production Cost and Minimum Diameters of Small Wood.

G. CALLIN.

Report of Statens Skogsforskningsinstitut (Stockholm) **38.6,** 52 *pp.* 1949-50. *in Swedish.*

An analysis of available data is made to determine the minimum diameter of wood that can be felled economically by present methods.

Time studies show that the greatest amount of labour per unit volume is applied with the smallest diameters and the relationships between time spent per cu. ft. and diameter are shown graphically for different types of tree and factors such as summer and winter cut and whether barked or unbarked. A number of diagrams are given showing costs and selling prices and relating the minimum economic diameter to the state of the market.

The Economics of Packaging Equipment for Export.

D. A. S. WILLIAMS (The Shell Petroleum Co.).

The British Packer. **12.** *Nos* 4, 5 *and* 6, *April* (33-34), *May* (30-32), *June* (32-33), 1950.

A general review is given of the losses which may occur due to bad packing and examples are given of how good packing can reduce damage and pilfering. An illustration is given in tabular form showing how the cost of loss can be calculated provided the normal period for payback on the goods and also the delivery time for replacement of losses are known. A distinction is made between loss to the user and loss to the country.

A generalised mathematical treatment is given showing how the minimum total cost (i.e., the sum of the cost of packing and the cost of loss) can be calculated. In order to solve this it is necessary to know the relationship between the cost of packing and the percentage loss. In the example given it is assumed that there is 100 per cent. loss when nothing is spent on packing, and that the percentage loss falls rapidly as more is spent on packing, until, with an expenditure on packing equivalent to about 12 per cent. of the original manufacturing cost, the loss becomes very small. It is suggested that this is probably a common type of relationship between loss and expenditure on packing, although it is pointed out that very little is known about it and there is an urgent need for statistical investigation.

Echo-Sounding and the Pelagic Fisheries.

WILLIAM C. HODGSON, D.Sc. (Fisheries Laboratory, Lowestoft).

Ministry of Agriculture and Fisheries; Fishery Investigations. **17.** (*Ser. II.*) *No.* 4. 25 *pp.* 1950.

This work was designed to help fishermen to get the best results from their echo-sounders when used as fish-finders. The history and many hints on the use of these instruments are given.

The most important discovery was that, by studying the echo-traces, it was possible to say which species of fish had been recorded. Herrings, pilchards, sprats, mackerel, cod, etc., were found to give echo-traces which were quite easily distinguishable. The report is fully illustrated.

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A characteristic of American business is the importance attached to scientific method in management. Two recently published volumes are concerned with this subject.

Proceedings of the 1950 Annual Fall Conference of the Society for the Advancement of Management

Published by the Society at 84 Williams Street, New York.

Many of the papers in this volume discuss the application of management tools such as quality control and work simplification, but about a third are devoted to the human aspect of management and the problems of securing effective communications, good incentives and a high morale.

Dr. ROBERT P. BRECHT discusses "The Logic of Efficiency and Its Acceptability in Practice." He warns those who are too certain of the validity of their management tools, when he says, "the logic of efficiency is apt to ignore the conditioning role of human effort and responsiveness." He suggests two dangers: first, the gap between sound management practices and the acceptance of those practices by those who implement them; second, the limitations of a survey of company practices as a basis for decision. He thinks that the latter emphasises conformity rather than uniqueness of managerial effort. "Imagine the present state of the medical arts if advance in that field were determined by surveys of current practice; 87.4 per cent. of the witch doctors report that dried toads' eyes are the best prescription for goitre."

Several of the papers emphasise the value of individual targets as an aid to increased production or better quality. In "Quality Control — A Tool for Human Engineering," Mr. ROSCOE SMITH, Director of Quality Control for the Ford Motor Company, advocates control charts for quality, and instances one job on which they were using 100 per cent. inspection, where defectives ran as high as 12 per cent. The use of chart control on this job cut defects to 1.4 per cent.

The application of incentives is dealt with by several speakers. Mr. FORD R. LARRABEE, of Cincinnati Industries Inc., describes the nine incentive plans they have in a 200-man plant. There are separate incentive plans for: plant, maintenance, foremen and superintendents, engineers, department heads, clerical workers, sales, laboratory head and laboratory, and executives. There is only room to refer to two of the more unusual of these incentive plans. The maintenance plan is a group plan on a weekly basis and has two measuring elements: maintenance labour cost compared to a budget for Dyer Unit volume levels, and a machine breakdown factor. The latter is worked by creating a fund, the full amount of which is distributed as bonus to the group, provided that there are no machine

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mechanical breakdowns in that week. When breakdowns occur, this fund is debited at a rate per hour of breakdown, which varies with the importance of the equipment. In the clerical workers plan, which covers payroll clerks, stenographers, secretaries, bookkeepers, the nurse, and clerical employees in general, the plan is monthly and is a per cent. of salary. To encourage co-operation between departments, the same per cent. applies to all participants. There are three basic elements of measurement: first, units earned against standards which are set by historical analysis rather than by the stop watch. Where the jobs cannot be standardised, as in secretarial work, the employees are granted a constant number of units for a substantial portion of their work. Second, a bonus unit for completing control reports earlier than the scheduled time. Third, the total time worked.

Another paper of interest for operational research is that by Professor MORRIS S. VITELES, Professor of Psychology, University of Pennsylvania, on "Man and Machine Relationship—The Problem of Boredom." Professor Viteles discusses the results of research in America, Britain and Germany. He says that there is no single cure for boredom and other effects of monotonous work, but that proper selection of those who are less susceptible to boredom (usually the less intelligent) and the substitution of varied for uniform work, as well as rest pauses and music all help to reduce boredom.

In a short review only a few of the papers can be mentioned, but the attention paid to the human aspect of management shows that in the application of operational research to management, human reactions can rarely if ever be ignored.

R. S.

Management in Motion.

NEIL W. CHAMBERLAIN (Assistant Director, Labor and Management Center, Yale University).

New Haven, Conn.: Yale University Labor and Management Center, 1950 (*pp.* vii + 124. $2.00)

The Yale Center has been studying human relations in the Southern New England Telephone Company and the Connecticut Union of Telephone Workers. This book describes one section of this pure research; a full case-study of one management decision. The book will interest operational research workers, firstly because, since operational research is carried out to prepare the way for executive decision, they should be deeply interested in understanding the mechanisms of such decision; and secondly, because at one point the case-study became pure research on operational research. The decision chosen for study was a decision substantially modifying the procedure within the firm for labour transfer at employee or supervisor request.

The study of the decision opened at the stage of a felt need for some change in the existing procedure; the sense of need led to a research assistant in the Company's employment office being commissioned to study the problem (this was the phase of "operational

research," although the name is not used in the case-study). Next the decision is traced through the committee processes, with especial reference to the extent to which the various persons more or less directly concerned were kept in touch with current thinking, to the formal decision, in 1945, represented by the approval at top level in the company of a policy Bulletin. The major part of the study, which covers the period 1945-49, deals with the second part of the decision process, namely that from the formal taking of the decision to its actual implementation in practice — "Those who act are as significant to the decisional process as those who state . . . Several groups other than the general managers must still make their decisions consistent with those of the latter group if the decision-in-action is to be identical with the decision-in-statement."

At this stage were revealed the consequences of the situation in the earlier stages, that although upward communication in management had been good, downward communication had been neglected. A major weakness was due to failure at the time of the formal decision to make it explicit that there had been a definite change in Company policy; indeed, the transfer policy was in 1949 still being condemned because of pre-1945 experience. The study brings out clearly the important part played by the supervisors, the employees of the Company, and the Union in transforming the policy set out in the Bulletin, and in making "the policy what in fact it was." One cause of lack of departmental co-ordination appeared to be "a general disrespect for the transfer practice, even though satisfaction is expressed with the transfer principle. "The case study included extensive interviews with supervisors and with workers, and brought out clearly the degree of misunderstanding which existed about the procedure; for instance, about half of the supervisors did not understand it at all adequately. During this second stage of translation of formal decision, there was (apparently) nothing of the nature of operational research. The case-study reveals that there had been real need for information to be available about the performance of the transfer scheme. The Employment Office "has not made full use of the information which is available to it in order to arrive at a practical answer to that question." [the reasons for which transfers are requested, or the work-performance of employees who have received transfers]. "It has never, for example, made any analysis to discover the length of time requests have been on file, or the number of times applicants have been rejected after having their names submitted to hiring supervisors, or the percentages of applicants who are successful in securing transfers. This information is available if wanted, but it has not been worked on. Neither has it been called for."

This is a book which operational research workers will put down after reading with a sense that they themselves have had experience of situations closely analogous to those which it has so clearly analysed; and perhaps with a sense, too, of wishing that they could themselves carry out a similar research on their own situation.

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OPERATIONAL RESEARCH QUARTERLY

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EDITORIAL NOTES

NON-MILITARY APPLICATIONS OF OPERATIONAL RESEARCH

THE committee on operations research set up by the National Research Council in the United States, described in the Operational Research Quarterly, 1950; **1** (3) p. 43, set itself an ambitious programme of encouraging the development and promoting the understanding of operational research. The valuable work done by O.R. teams during the war is by now widely recognised, and those who know most about that work are convinced that the same techniques can play a great part in the efficient running of the complex organisations which go to make up government, industry and commerce in peace-time. It must be admitted, however, that others are not so convinced or, being convinced, none the less disregard O.R. as nothing but a new name for an old garment. In either case the root cause of their apathy is usually lack of knowledge, and to combat this the first task which the Committee on operations research set itself was to prepare an educative pamphlet giving a brief, untechnical description of the main features of O.R. for leaders of U.S. enterprise and government and for scientists. This brochure has now been published.*

It starts by giving definitions of O.R. which, however, it rightly says must be supplemented by examples of problems actually solved if a proper idea is to be given of its methods, characteristics and significance. Proceeding to consider in more detail the types of problem which O.R. can tackle, however, the discussion is kept very general and, apart from a few fleeting references, little information is given about specific operational research work other than military. This was no doubt unavoidable if the brochure was to be kept brief. It was also, no doubt, at least partly due to the difficulty of presenting a balanced picture by reference to published work since so much that has been done, particularly in the U.S.A., is highly competitive and

* Operations Research with Special Reference to Non-Military Applications. *Prepared by the Committee on Operations Research,* 12 *pp. Available from National Research Council,* 2101 *Constitution Avenue, Washington, D.C., U.S.A.*

therefore remains coyly in secret or confidential files. This absence of detail, however, is unfortunate as it may well be interpreted by the sceptics as a weakness in the argument; it therefore underlines the urgency of ensuring that the fullest possible publication of operational research work should be achieved.

The description of possible fields for O.R. in industry proceeds by analogy with war-time examples which are classified as dealing with weapons, tactics or strategy, although the distinction between these three is by no means always clear-cut. Non-military O.R. in the first class might be concerned with the study of design and arrangement of machines, signals, controls, etc., and with the setting up of measures of efficiency; here O.R. overlaps with industrial engineering and other disciplines. One definition of tactics is given as "the art of disposing of forces in actual operations according to definite procedures for gaining some end." Such tactical problems might concern the scheduling of processes, the best use of plant, the routing and control of traffic or the conduct of a sales campaign. Strategical research, which must be based on sound material and tactical studies, will be concerned with the broader aspects of industrial organisation, marketing, personal relations, etc.

The brochure is careful to explain that O.R. does not supplant but fortifies executive judgment. There is, however, a suggestion that the limitations on O.R. are synonymous with the limitations on the use of numerical analysis and controlled experiment, an argument on which both Dr. Easterfield and Mr. Sargeaunt had definite views in our last issue.

The claim of O.R. to be something new is based partly on its special relationship to management as has been stated by earlier writers (e.g. Professor Blackett in our first issue), but this is supplemented by a claim to inclusiveness. Thus although O.R. may use special techniques, such as time and motion study, these are but a part of it and it puts together many disciplines into one whole.

We welcome this pamphlet as a thoughtful study which will help to extend interest in operational research. We come back, however, to the point we made earlier, that the best persuasion is by example.

Operational Research Club

The first meeting of the new session will be held on Wednesday, October 31st, in the Committee Room of the Royal Society, when a paper will be given by Mr. R. T. Eddison, of the British Iron and Steel Research Association, on *Importing Iron Ore*. The chair will be taken by Mr. D. Hicks. Tea will be taken at 4.45 p.m. and the paper will be preceded by the Annual General Meeting.

Marshalling and Queueing will be the subject of the Club's open meeting in March, 1952, details of which are now being arranged. Members of the Club are invited to communicate to the secretary any ideas they may have on contributors or contributions.

No other nominations having been received, the Committee of the Club for the 1951-52 session will consist of Sir Charles Goodeve, Mr. D. Hicks, Mr. A. W. Swan and Dr. O. H. Wansbrough-Jones.

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OPERATIONAL RESEARCH IN RETAILING

by JOHN BAXTER, Ph.D. (Econ.)

OPERATIONAL RESEARCH in retailing covers three main fields.

1. The study and analysis of the habits of people as consumers and the consequent adaptation of the art of shopkeeping to conform with these habits in the best possible way.

2. The continual investigation of the operation of the organisation of the store in order to raise efficiency.

3. Finally the study of the merchandise being handled in order to improve its quality, facilitate its supply and to reduce its cost.

All these fields of course overlap. Their relative importance will vary with the type of retail firm concerned. It is usually considered to be mainly the function of the manufacturer to solve merchandise problems, for example, but there is a growing realisation that the retailer has his own special contribution to make.

While operational research as such is not common in retailing much of the work done by management, merchandise and personnel departments can be classified under this heading. The object of this paper is primarily to outline the type of problem which lends itself to this method of attack, and to indicate how far, either consciously or unconsciously, this approach has been successfully applied. Only general principles will be mentioned: further detail is given only if it is necessary to illustrate the points raised.

First of all an appreciation of the problems involved requires a clear conception of the function of retailing. There are many definitions of this but, for present purposes, the following appears to be adequate. It is the function of retailing to provide focal points in which the general public, as consumers, can satisfy their needs. These focal points cover a wide variety of different types ranging from the market stall to the "universal provider." They include a range of methods varying from complete "self-service" to highly organised systems of credit, delivery, after-sales service and sometimes even of manufacture of goods to meet special requirements. Operational research can only be an economic proposition for the large concern, and it is the approach of the large retail organisation to this which is considered in this paper. At the same time the lessons learned can often be adapted to the needs of smaller units.

It is useful to consider the types of investigation necessary from two aspects—the relationship of the retailer with the public and with the merchandise.

The Public

Retailers cannot exert the same control over their operations as is possible where purely mechanical processes are concerned. In catering for the public they are subject to the vagaries of persons. This means that a highly elastic form of organisation has to be evolved.

The first problem therefore is that of the collection of facts about the behaviour of the general public in so far as this impinges on the work of the shopkeeper. On the basis of such facts the organisation required is shaped and the equipment to be used is designed.

There is a general pattern in consumer behaviour which can be analysed and broken down into frequency distributions based on the number of shoppers at different times of the day, on different days of the week and at different seasons of the year. Knowledge of the peak periods thus revealed is very important in determining strategy. These patterns will vary in different ways according to the merchandise being offered and the environment in which the shop is situated. They are not static but subject to continuous change. Such changes are often caused by developments in social habits and in social conditions.

In the United Kingdom in recent years, for example, several factors have caused important modifications in public habits. The general introduction of the five-day working week in industry has undoubtedly caused a redistribution of retail business during the week. In the same way the continuation of the war-time custom of closing early—at 5.30 or 6 p.m.—has resulted in fundamental changes in shopping habits as compared with pre-war days. The rise in the number of housewives who now go out to work has caused similar changes. Such variations are, of course, soon realised by the alert shopkeeper. The merchant instinct is very strong in this respect. It is much better however for these trends to be assessed on a scientific basis. It is important for some system to be devised for maintaining a regular check upon what is happening. Important work has been done in this direction particularly by some Continental department stores. There are important possibilities of further development in this field. With rising labour costs anything which can help to increase the output of those employed merits very close attention.

A simple study of the number of customers served per hour in the various departments of a store gives a useful basis for planning. Such information is not difficult to collect. An inspection of cash registers each hour will usually yield sufficient facts for a working formula. One result of investigations of this type carried out by some department stores has been the creation of mobile teams of sales staff which are available for use to meet peak demands. On the basis of the information collected in this way their probable movements can be estimated in advance. Furthermore Supervisors can be given a clear indication of when and in which department these peaks will occur.

Another profitable source of enquiry lies in the study of the flow of traffic in a store. This is especially valuable in large units and in department stores. Experience shows that customers tend to follow fixed routes inside a large shop. These routes are affected by the position of the entrances and exits, by the siting of lifts and escalators and by the position of display stands and counters. The problem has two aspects: the flow of traffic on a given floor, and the relationship between one floor and another. The facts are very important in any consideration of the interior design and lay-out of new buildings and in decisions regarding the siting of departments. The position of the different departments in relation to each other and the position of individual lines of merchandise within a department should be

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considered against this background of the pattern of customer traffic. The maximisation of takings is achieved when the proper relationship between these variable factors is established.

The importance of these studies of customer behaviour lies in the effect they have upon the allocation of sales staff to different parts of the store; in the use made of mobile assistants to meet peak demands which may occur in different departments at different times; in the relationship between the location of reserve stocks and selling points; in the physical design of counters, show cases, and reserve stock storage facilities. Accurate knowledge of these factors also has a bearing on display requirements and even on matters of ventilation and lighting. When store and department managers are given facts of this type they can so adapt resources as to add materially to turnover in the departments concerned.

Apart from the habits of the public knowledge of their physical characteristics is also of great importance. Knowledge of age distribution, height, weight and colouring can have a very great influence on buying policy and stock requirements.

The Merchandise

One of the constant aims of any retail organisation is to maximise turnover while keeping stock down to a minimum. In other words a measure of efficient retailing is the ratio between sales and stock. Expressed in terms of the number of times stock is turned over in a year the higher the level, other things being equal, the more efficient is the organisation.

There are two fundamentally different approaches to this problem. They can be classified broadly as the chain store approach and the department store approach, although of course the methods involved are not necessarily confined to either of these two types of retail organisations. The object of the chain store is always to concentrate on the fastest selling merchandise and to eliminate slow sellers. The department store on the other hand aims at ensuring that a really comprehensive stock is carried—a stock which is sufficient to meet any probable need on the part of the public but which at the same time is kept to a level which ensures the most economical use of the floating capital which is employed.

There are alternative basic statistical measures which may be used in a chain store; sales per foot of counter space, and profit per foot. In principle the two are the same—they merely differ in emphasis and in the approach to the problem. From an operational point of view the question in each case is how to obtain quickly, comprehensive statistics of sales and stock on a weekly or a fortnightly basis and to set up some system which will ensure the rapid translation and interpretation of the results into action in the stores. This is achieved through the use of simple forms which can be completed by the sales assistant for the merchandise under his or her control and the coordination of the information on these forms by mechanical methods in a central statistical department. The standards which are applied are either the average takings per foot or the average profit per foot. In either case the method followed is to expand the space given to merchandise which exceeds the average and to reduce the footage

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given to merchandise below average. This is followed, if necessary, by the elimination of those lines at the bottom of the list. In this way the average is maintained at the highest possible level and the maximisation of turnover is achieved. This system is semi-automatic in its application and is simple to control.

The approach described above is excellent for those organisations which concentrate their efforts on a restricted catalogue of lines. The department store however, while perhaps no longer a "universal provider," is nevertheless more concerned with meeting as large a sector of the public's requirements as possible. By the very nature of the case much of the merchandise carried must have a relatively low rate of stock turn. At the same time the number of individual lines is far greater than that carried by the chain store or the specialist shop. It is therefore not possible to have simple comprehensive systems of control and much more has to be left to the buyers of the departments concerned. Unlike the chain stores which do a cash trade only, the department store normally has a large proportion of credit customers and this calls for a much more involved system of accounting than is necessary in those concerns where cash trading is the rule. Nevertheless much work has been done in studying the problems of stock control in relation to sales. Equally important perhaps, from the department store point of view, is the knowledge of its customers which can be obtained from a statistical study of its credit accounts. As advertising is much more important for these organisations the information concerning customers—where they live, the type of goods they buy and the amount they spend—is very important in considering advertising programmes.

Another wide field for development for all retailers is that of relating buying policy to public demand. This is more than merely maintaining supplies of different lines of merchandise to meet variations in sales in the stores. At its best it means developing a system which will enable bulk buying of basic materials to be combined with the greatest possible degree of variety in the finished products. To take one example, this can be achieved by a complete analysis of the types of cloth used in textile departments. Studies of this kind show that garments of widely different types can be produced from the same basic cloth, variations being obtained through printing and dyeing. The application of this principle in practice means that the full economies of bulk production of standard types of cloth can be combined with a very high degree of flexibility in the end use to which the cloth is put. It means not only economies of this type but also the ability on the part of the retailer to switch production quickly from one type of product to another to meet variations in sales. To accomplish these results special departments have to be established, staffed by technically qualified people who are able to devise specifications which will meet these requirements.

Conclusions

Operational research can be a powerful tool for management in retailing. While some firms have already developed it to a considerable extent, it is still something new in organisations of this type. Not all the problems involved are capable of solution on the basis of precise scientific and statistical investigations but where such pro-

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cedures can be followed they can be of very great assistance.

Many of them are concerned with the behaviour of people as a group and special methods need to be devised for studying this.

How far it is possible by these means to increase the efficiency of distribution is not certain but substantial improvements have been made in some cases. There is no doubt that such investigations are well worth the time and expense involved.

NOTES FROM U.S.A.

We learn from Professor C. West Churchman of the Case Institute of Technology, Ohio, that the Engineering Administration Department at the Institute intends to hold "a three or four day conference, probably November 7th and 8th, on the application of operations research to problems of business and industry." It is hoped that a member of the (British) Operational Research Club will address the Conference on Operational Research in the United Kingdom.

It is interesting to see that in the United States, Operations Research has become a subject for correspondence study. A New York correspondence school offers a course in Operations Research for 32 dollars with the following syllabus:

Methods of scientific research in tactical operations and their effects, developed in the British and American armed services during World War II, known as "operations research." The meaning of operations research; examples of its use; its significance. Mathematical methods for solving problems in operations research. Techniques for getting information, formulating the problem, manipulating the data, drawing conclusions, and presenting conclusions to appropriate executive authority. Applications to military problems that have been declassified and published. Applications to business and industrial problems. PREREQUISITES: *elementary calculus and statistics.*

ABSTRACTS

The Back Room Boys Go Into Business.

GEORGE HILLYAR.

The Director, July, 1951; **2** (10) 66-68.

Operational Research is described as a new tool offered by science to business and is stated to have interesting possibilities for directors concerned with production and marketing problems.

Most of the better-known war-time examples of O.R. are reviewed in general terms and, to show what is being done in industry, reference is made to the work of the Shirley Institute, the United Steel Companies, Road Research Laboratories and the British Boot, Shoe and Allied Trades Research Association.

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Time and Gasoline Consumption in Motor Truck Operation as Affected by the Weight and Power of Vehicles and the Rise and Fall in Highways.

CARL SAAL (Bureau of Public Roads).

U.S. Highway Research Board Report No. 9A. *Washington,* 1950. 74 *pp.*

This investigation was designed primarily to produce two components of the direct operating costs, namely, fuel and time, for heavy commercial vehicles of various types, powers, and gross weights. While the opportunity was taken to make other observations which will be of use for other purposes, e.g., maintenance costs, great care was taken to keep conditions such as grade of gasoline, climatic conditions, vehicle condition, driver behaviour and traffic volumes constant, so that the only factors which would cause two sets of results to differ would be the weight and power of the vehicles and the profile of the road.

The problem of finding some yardstick to measure the hilly nature of a road route was met by the use of the ratio " rate of rise and fall ". This was obtained by adding together the vertical rise of each uphill portion and the vertical fall of each downhill portion, and dividing this total by the total length of the route. When travel in one direction only is involved, the percentage rise in the direction of travel is also required.

From the results, graphs have been prepared enabling gasoline consumption or travel time to be determined. In addition formulæ, which correspond with these curves, are given for use where they are more convenient.

Examples are given of the calculation which can be carried out, using these relationships, but figures obtained in this way must be used with a certain degree of caution. Unless the conditions are similar to those of the tests, the information derived will not necessarily agree with actual results. The real value of the information in this report lies in the ability to make comparisons. If the time and gasoline consumption over an existing route, and over the same route with proposed realignments, are calculated, the ratio between the consumptions would be a fair measure of the advantages or disadvantages of the realignment. Similarly, comparisons can be made to ascertain the probable effect of changes in the power-weight ratio of the vehicles, or of transporting goods in vehicles of a different capacity.

Employment Relations in a Group of Hospitals.

JOAN WOODWARD. (University of Liverpool.)

The Institute of Hospital Administration, 1950. 115 *pp.*

An investigation is described into the morale in the Central Wirral Group of Hospitals ; this was undertaken by the Department of Social Science of the University of Liverpool at the request of the Hospital Management Committee.

Reference is made to the value of routine statistics on absenteeism, accidents, etc., as measures indicative of morale. The report is, however, mainly concerned with a description and the results of an

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attitude survey undertaken specifically for the investigation. The type of attitude survey used was based on the system of free answer interviewing, a set of leading questions being prepared for each interview and the persons interviewed being encouraged to put forward his own ideas and opinions within the framework of these questions.

It was decided to use a 25 per cent. sample and the reactions of the staff are discussed under three main headings; these are supply and utilisation of hospital staff which includes recruitment, selection and training and promotion; conditions of work including problems of residential employment, environment, health and safety, rates of pay, etc.; and human relationships with other individuals and staff groups as well as with supervisory and management grades.

Some general conclusions are drawn about the morale in the hospital group based on the numbers expressing satisfaction or dissatisfaction with conditions under the various headings. Special attention is also given to two questions which were asked; these were whether those interviewed thought the hospital was a happy place and whether there were any changes they would like to see introduced. The fact that a large number of constructive suggestions, in many cases dealing with the well-being of the hospital as a whole, was made in answer to the second question is regarded as showing a lively interest and therefore symptomatic of high morale. Finally some recommendations on particular aspects of personnel policy are made.

Physics Abstracting.

DWIGHT E. GRAY (American Institute of Physics).

Amer. J. Phys., Oct., 1950; **18** (7) 417-424.

The report describes a study made to provide the Joint Committee on Abstracting of the American Physical Society and the Institute with information on which to base realistic recommendations for the improvement of abstracting in the field of physics. The principal object was to answer the questions: For what purpose do U.S. physicists use abstracts of physical literature? What is their opinion of the physics abstracting now available to them? What, within reason, would they like to have in the way of physics abstracting?

The method of the survey was by questionnaire and interview. Because of the prejudice towards questionnaires every effort was made to keep the questionnaire as short as possible and to avoid unnecessary questions. It was sent to 2,128 physicists, of whom 1,628 returned it, 1,477 having filled it out essentially completely. A slightly modified questionnaire was also sent to 300 technical and reference librarians, of whom 202 returned answers. Interviews were severely restricted owing to limitations of time, staff and funds. In the analysis of the questionnaire answers, the physicists could be subdivided according to age, specialist subject and type of employment.

Many of the questions were designed to discover the use made of particular abstracting services and opinions of them. On the more general questions regarding the kind of abstract preferred the qualities considered important and the reasons for using them, a number of

interesting conclusions are given. For example, wide coverage of technical journals was considered the most important feature, with prompt publication as second. The physicists who were interviewed stated almost without exception that seldom if ever would they accept technical data given in an abstract without themselves checking the original and that therefore they really required only abstracts which would tell them with certainty whether the papers contained material of interest to them. Nevertheless, they were heavily in favour of informative abstracts written by experts rather than staff-written indicative abstracts. The provision of such expert, informative abstracts normally involves delay, which conflicts with requirement of prompt publication. The report concludes with suggestions that the provision of author-abstracts published with each paper should be encouraged, suitable safeguards being taken to ensure that the quality of the abstract is up to that of the paper.

Operations Research.

HERBERT SOLOW.

Fortune, April, 1951; **13** (4) 105-7 *and* 146-8.

The position of the operational research scientist in business is likened to that of the agricultural scientist who, without being a farmer, can tell farmers many things that they should know; to illustrate this, reference is made to the work of Dr. H. C. Levinson in L. Bamberger & Co., and other indications are given of the growing importance of O.R. in industry.

The origins of O.R. in wartime are traced, and there is some discussion of the difficulties of definition and of its proper function in relation to executive decision and old-line management consultants. The qualifications required in an O.R. scientist are considered and some indication is given of the techniques employed; mathematics and statistics provide the basis of these but that is not all and wider disciplines are often required.

A real industrial O.R. job is worked through in a disguised and simplified form. The problem was how to plan production for a sharply seasonal market, and it proved possible to determine the proper balance, to minimise total costs, between steady production throughout the year (with low production costs and high inventory costs) and production fluctuating in line with demand (with high production costs and low inventory costs).

Operational and Statistical Research in Building.

J. BRONOWSKI (National Coal Board).

Economic Commission for Europe, Proc. Conference on Building Research. Dec., 1950. *pp.* 137-151 (*Reproduced in The Architects Journal, 29th March,* 1951; **113** (2926) 403-6.

The aim of science is to conclude from what has already happened what will happen next time. Mathematical statistics provide a technique for making use of operational data, with all their variability, for this purpose as well as controlled laboratory experiments. Statistics enable operational variation to be studied; as an example

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reference is made to the study by the Ministry of Works of the building of traditional and non-traditional houses at a number of sites (vide *O.R. Quarterly* **1**, *No.* 2, 30-31).

Another statistical technique useful for collecting operational data is sampling. By collecting data from a representative number of firms information can be obtained far more cheaply, and often more accurately and in greater detail, than by a full census of the industry. Thus the records of a 3 per cent. sample of builders working on traditional three-bedroomed brick houses being built all over the country enabled the Ministry of Works to give average man hours and costs and their inherent variations; to find the effect on them of paying a bonus; to isolate trends in labour and material costs over two years; and to show the effect of other variables such as size of house and number of houses on a site. It was further possible to show the builders how much helpful information was hidden in their records and how much more could be obtained from better records.

The Representation of Labour Turnover as a Social Process.

A. K. RICE, J. M. M. HILL, and E. L. TRIST. (The Tavistock Institute of Human Relations.)

Human Relations, November, 1950; **3** (4) 23 *pp.*

The Labour turnover process is examined in two factories where, as a result of the current full employment situation, leaving has been largely of the employee-request type.

Two main kinds of fluctuations in labour turnover were found:

(a) short-term fluctuations produced directly by short-term personal and social forces, since the nature of the work contract allows individual leaving decisions to be effected without delay;

(b) longer-term fluctuations produced by gross social and economic forces.

When these two kinds of fluctuations were accounted for there remained a level of turnover which was relatively constant for the institution in which it occurred.

The total turnover process (from engagement to termination) is represented by a frequency distribution of the lengths of time which leavers, who entered the firm in given periods, survived. The resultant distribution, the greater part of which may be described by a hyperbolic function, shows the total turnover process to have three identifiable phases which have been called the period of induction crisis, the period of differential transit, and the period of settled connection.

The investigation has so far been limited to two industrial institutions. Differences discovered between them suggest the possibility that the form of the pattern of the turnover process may vary for different kinds of institution having different conditions of attachment and separation and different institutional cultures Some implications on labour policy are considered.

Planned Seeing: Some Psychological Experiments.

F. BARTLETT (Cambridge University) and N. H. MACKWORTH (Medical Research Council).

Air Ministry Air Publications 3139*B*. *H.M.S.O.*, 1950. 76 *pp.*

The report is in two parts, the first dealing with visibility in control rooms of fighter command. The main aim of this research was to provide experimental evidence on human visual performance which could be used to plan conditions to suit all working in the control rooms and to replace guesswork in design of rooms and equipment.

The visibility tests are described under three main headings: grid reference reading, visibility of arrow direction and legibility of capital letters and numbers. In each case a group of members of the W.A.A.F. was used for the tests; all the subjects had good eyesight and were experienced at the work. The procedure was to determine the number of errors made with a variety of different viewing angles and distances. The effects of widening the grid lines, colour contrast and arrow shape and size of lettering were considered. The conclusions show that the viewing distance and viewing angles are of the greatest importance.

The second part of the report deals with the training of pathfinder air bombers in visual centring on target indicators. The main part of the work described is not operational in that it consists of the use of an apparatus in the laboratory, though the apparatus is designed to simulate operational conditions. The accuracy of aimers in centring is determined using this apparatus and the improvement in accuracy with training is demonstrated. Finally, the assessment of aimers with the apparatus is compared with two operational assessments, viz. (i) the Squadron Bombing Leader's grading, (ii) operational records during night raids. No agreement whatever could be found between any two of these three measures; while this may be due to insufficient operational evidence, it may be due to factors such as weather conditions, accuracy of bomb-sight and enemy opposition which are present in operational conditions but are not simulated in the apparatus.

Operations Research.

HORACE C. LEVINSON (National Research Council) and ARTHUR A. BROWN (Navy Operations Research Evaluation Group).

Scientific American, March, 1951; **184** (3) 15-17.

Operations, or operational research is seen to be something new in that, as first applied during the war, it brought scientific methods to bear on tactical and strategical problems, on the use of weapons rather than on their development; it is concerned with the analysis of situations and of the efficiency of various systems of organisation for coping with them. This approach can be applied to business and governmental organisations as well as military ones. Diverse problems can be handled but the problem must satisfy two conditions;

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it must be expressible in numbers or quantities and the data must be adaptable to available techniques.

A number of wartime examples are described; the use of radar; the attack on submarines; the availability of aircraft; and the response of ships to Japanese Kamikaze attacks. As an illustration of operational research technique, the sweep rate is defined and its use described. Finally operational research in business is illustrated by details of a study of the effectiveness of department-store newspaper advertising. The particular type of advertising studied is referred to as quick-response advertising the object being to produce immediate sales. The value of the advertising however, depends not only on the value of the sales of the particular commodity advertised but on its effect on total sales of the store. Methods were devised to determine the effect of advertising campaigns on total sales over a period of time. The value of the advertising was determind and factors affecting its efficacy were isolated.

Book Reviews

Methods of Operations Research

by

Philip M. Morse and George E. Kimball

Published by the Technology Press of Massachussetts Institute of Technology and John Wiley and Sons, Inc., New York. Chapman and Hall, Ltd., London, 158 *pp.* 32*s.*

Reviewed by

E. C. Williams

This book is the first of its kind; and, as always in a pioneer venture, the task of the reviewer and of the critic is several orders of magnitude easier than that which was the author's. It will, perhaps, be disappointing to the general reader that all the examples given in the book, with the exception of a few descriptive ones in the first chapter, are military (and, within that, predominantly concerned with the war at sea). Either commercial secrecy is greater than military security, or a comparable civil body of achievement does not exist or is not widely known. However, the authors cannot be blamed for that, nor for the fact that there are still military examples which they are not allowed to use. The alteration of some of the figures in some of the examples does not detract from their illustrative value. There are some algebraic and arithmetical obscurities which earnest students will, no doubt, point out to the authors in due course.

The history of the book has determined its form. It was originally written by Morse and Kimball at the end of the war as a classified report, one of a large series written in the United States to put on record scientific and technical achievement in the war. For open publication, the first and last chapters have been re-written, but

chapters 2 - 7 remain as they were ; so much so, that they still contain, at least on pages 13, 30 and 39, mysterious references to " Division 6, Volume 2B," which appears again on page 86 as " another volume in this series." This present book was Volume 2A of the particular series ; perhaps the reason for the survival of these references is that the Chapters 2 - 7 are printed from the original typesetting, no doubt for economy and speed of publication.

The definition of Operational Research used is the one first formulated by Goodeve, about which there has been so much elaborate (and futile) discussion. This is not the place to add to the confusion, but it is possible that the germ of a better (and simpler) definition is fortuitously present in the last sentence of the first paragraph of Chapter 3 on page 38 : " the improvement of operations . . . by the application of scientific analysis . . ."

Chapter 2, on " Probability " is as good a potted version of the subject as can be found. Pure-minded mathematicians may find some of it unorthodox, but for the O.R. worker it is none the worse for that. The quality of the treatment will not be denied.

Chapters 3 - 7 are essentially military and it will be necessary for the civil or industrial operational research worker to choose his own analogies. It is fair to remark that much of the work described is British in origin, though not always directly acknowledged as such. The origin of the book has influenced the emphasis throughout these chapters. The purpose at the time of the first writing in 1946 was at least in part to record what had been done and what had been important. No doubt new authors will be able to take a wider view and, with benefit from this book, give a smoother, wider and more balanced set of examples. Those given are well chosen and presented.

Chapter 3 describes some of those " measures of effectiveness " which are found so useful in military operational research, and it implies the importance that such measures must assume. The little homily on " hemibel thinking " at the beginning of the chapter is to be recommended to all workers in this field, but juniors should not take it too literally. Chapter 4 (Strategical Kinematics) contains the best information there is on Lanchester's equations and some development of them, and some notes on the minimax principle and its use. Chapters 5 and 6 (Tactical Analysis and Gunnery and Bombardment Problems) which are decidedly military will have to be searched by the civil worker for analogy of method ; perhaps the most useful will be the sampling method on pp. 122 et seq. Chapter 7 is a short description of operational experiments.

Chapter 8 (Organisational and Procedural Problems) must have been very difficult to write. It is mainly derived from U.S. Navy experience, and may not be widely applicable. We must await the publication of other experience before we can take a composite view.

Apart from operational research workers who must obviously read this book, anyone interested in new applications of the scientific method should read it. It is particularly valuable in showing, for the first time in an open publication, the wide sweep of military operational research, and it will, it is hoped, destroy the lamentable identification of operational research with statistics which threatens in this country.

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The Foreman: A Study of Supervision in British Industry
by the
National Institute for Industrial Psychology
Published by Staples Press, London. 158 *pp.* 12*s.* 6*d.*

This book describes the scope, methods and results of the first two years of a study of supervision in British industry which was undertaken in 1948, and is still continuing. It is based on visits to 107 firms, interviews with 752 supervisors, replies to a questionnaire from 751 firms employing more than 250 persons, a study of the literature on supervision, and visits to organisations providing supervisory training courses. In addition, trial selection procedures and training courses for foremen were carried out by the investigators, and are reported. Although the investigation itself does not fall strictly within definitions of operational research, in so far as it was carried out by an independent body not working specifically for an executive, the book is nevertheless of interest to operational research workers.

The investigators begin by distinguishing four levels of supervisors: The senior supervisor, in charge of a large or important shop; the foreman, engaged wholly in supervision with some responsibility for planning and organisation; his assistant, with more limited responsibilities; and the working chargehand, who is normally an operative, but has some responsibility for supervising others. The study is focused on the second of these, though much of it concerns the others as well. The nature of the supervisor's work is first examined, the demands it makes on him and the way these demands are affected by size of factory, complexity of organisation, relationships with others, age, pay, privileges, and numbers controlled. His varied responsibilities and authority are discussed and the qualities of character, disposition, judgment, etc., required to carry out the job satisfactorily. It is shown that the requirements fall into three groups, technical, administrative, and human relations, and, although the abilities required in these fields vary greatly between different supervisory posts, some proficiency is required in each.

The selection of foremen is next examined. Only 9 per cent. of the firms visited had full systematic methods of selection, 19 per cent. had rudimentary systems, and 72 per cent. relied entirely on *ad hoc* nomination. Nearly all the foremen interviewed had been selected by the last method, which had produced fairly good results, since both investigators and managers agreed that about 90 per cent. were satisfactory, and of these 16 or 17 per cent. were "first-class." However, it is pointed out that the changes that are taking place in the social order of the country, and in industrial organisation, are changing the supervisor's position, duties, and authority, and methods which worked well in the past may be less suitable for the future. Indeed, half the firms taking part in the investigation considered that there was need to develop more systematic methods of selection.

It is shown that in spite of the variety of duties carried out by foremen, a job specification is possible. A "concentrated" selection procedure to form a pool of potential supervisors, and a "continuous" selection procedure to replenish the pool and ensure that regular reviews are made of men who may be suitable for promotion, are described.

The next section surveys the training of supervisors. Existing facilities include part-time courses in technical colleges, residential courses

and internal courses in firms. The aims of a supervisory training policy are discussed and suggestions are made for the plan and duration of a training course. It is concluded that there is both a need and demand for further facilities, but it is stressed that training can only be fully effective if managers are themselves appropriately trained and in sympathy with the aims and content of the courses. This particularly applies to training in human relations.

Finally, before summing up the whole investigation, the position, relationships and status of supervisors is discussed, in order to show how best to give them the necessary support and conditions for carrying out their work. Although it is usually acknowledged that supervision is part of management, it is not always recognised how different the foreman's duties are from those of other managers, in his direct and constant contact with the men working at their daily tasks. Nor is it always realised how modern developments have tended to take away some of the foreman's prestige, for example by removing his authority to engage and dismiss workers, and by complicating, and in some cases obscuring, his position in the direct line of control by the introduction of specialist departments. In some cases it is found that foremen are responsible to more than one person, are given responsibilities without the authority to carry them out, and are ignored in the chain of communication from higher management to the men, by being omitted from joint consultative committees. A foreman's pay is not always sufficiently higher than the average of the men under him, to make his job attractive financially, and his duties are not always properly defined. It is not suggested that these faults are widespread in industry, but enough evidence of them has been found to emphasise that firms should study and review the role and status of their foremen, and should realise that while the foreman holds a key position in industry, he is often holding it against considerable odds. I. M. S.

A.S.T.M. Manual on Quality Control of Materials. Presentation of Data

American Society for Testing Materials, 1916 *Race St., Philadelphia, Pa., U.S.A. Special Technical Publication* 15—*C ;* 127 *pp.* $1.75.

In an age when calls for standardisation are the fashion every attempt to codify conduct needs most careful examination. One does not, however, need to read many scientific papers to realise how much easier the reader's lot would become if there were a little greater consistency on the part of authors in their presentation of data.

The book is in three parts. The first deals with the presentation of statistical data generally ; the simplest graphical methods are shown and the various parameters which must be known in order to define a population are discussed and the relative values of each in different circumstances are indicated. The second part deals with confidence limits and their calculation, and the third with the calculation and construction of various types of control charts.

This book is primarily concerned with quality control and its treatment of the more general statistical matters may appear rather elementary. It is, nevertheless, of interest to all those concerned with writing scientific reports based on numerical data ; among them operational research workers must be included although, since their audience is often non-technical, they may sometimes feel that the recommendations are not applicable. R. T. E.

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OPERATIONAL RESEARCH QUARTERLY

VOL. 2 NO. 4. DECEMBER, 1951

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EDITORIAL NOTES

ROBBING PETER TO PAY PETER?

RECENT correspondence in *The Times* provides an illuminating example of the need for operational research in matters of broad economic policy. The subject was the incidence of taxes required to pay for food subsidies and a disturbing lack of real data was revealed, even though several eminent economists took part. Indeed, much of the argument was concerned with some shadowy figures put forward at an early stage by an advocate of the subsidies, who was at length persuaded to quote the authority for his figures. The correspondence closed with that alleged authority, who had not previously intervened, declaring *"So far as I remember I have made no such studies."*

All this is good fun, but the subject is important and the lack of information serious. The correspondence was started by Professor Jewkes, who suggested that it was likely that even the poorest families paid as much in consumption taxes (i.e., beer, tobacco and purchase tax) as they obtained in food subsidies. If so, it seems rather absurd to tax people in order to give them a subsidy, a process which at the very least will involve considerable administrative waste; better, surely, to cut the subsidies and the consumption taxes by equivalent amounts.

Surely; but is the premise true that even the poorest families pay as much in consumption taxes as they gain from food subsidies? This is the crux of the matter and the weak point in Professor Jewkes' argument—a target on which his opponents were quick to train their guns only to find they were loaded with blank ammunition. In short, nobody knows. The only factual evidence brought up in the course of a long correspondence referred to recent work by Rowntree & Lavers on social conditions in York, where the abolition of food subsidies would increase the number of families in distress from under 5 per cent. to over 16 per cent. No doubt. The value of food subsidies to a family can be readily calculated with fair accuracy from a knowledge of the size of the family on the reasonable assumption that no individuals are far from the average in their consumption of subsidised foods. Considerable information on this point is available

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from Ministry of Food surveys, as Dr. Norman Wright mentioned in his paper to the O.R. Club last February. But nobody has attempted to suggest that the food subsidies do not, in fact, keep down the prices of the foods subsidised. The point at issue is whether it would be possible to reduce consumption taxes by an amount equivalent to the food subsidies in such a way that even the poorest families gained as much in tax relief as they lost by increased food prices. To decide this it must be known how much per head the poorest families pay in consumption taxes, and it would be highly dangerous to assume that the indirect taxes they pay are near the average for the whole country. This appears to be a question which can only be answered by direct observation, by survey or similar means. Whether a special survey would need to be undertaken or whether there is already evidence available in the Social Survey, or similar body, which would enable the question to be answered with sufficient accuracy is a matter for enquiry.

It is, of course, manifest that not all families are equally affected by the subsidies and taxes. Thus families with many children may be expected to pay less per head in beer and tobacco duty than families with few children, although the value of the food subsidies per head would be approximately constant. This led some correspondents to suggest that the most sensible thing to do to balance a reduction in food subsidies would be to increase family allowances, pensions, etc., which would directly benefit those who are most dependent on the food subsidies. The Ministry of Food surveys must have supplied figures which would form a reasonable basis for calculating such a balance. *The Times* suggests it can be reckoned broadly that for every £2 14s. taken off the bill for general consumer subsidies about £1 would have to be added to the bill for pensions, family allowances, school meals and the like to avoid reducing the standard of living of the groups protected by the welfare services. This, of course, is only illustrative ; it seems likely that the suggested addition of only £1 to pensions, etc., is rather an underestimate, particularly when it is remembered that even pensions and family allowances are not 100 per cent. efficient in ensuring that succour is only given to those who need it.

A further objection to the removal of food subsidies raised by some writers was that it would cause a rise in the Interim Index of Retail Prices which would inevitably, in some cases even automatically result in new wage demands. A corresponding increase in family allowances would not, it is true, be reflected in the Index; many consumption taxes, particularly beer and tobacco, are on the other hand well represented in the Index. It has not been unknown in the past for a Chancellor to select certain taxes for adjustment solely because of their effect, or otherwise, on the Cost of Living Index; it should not be impossible, if it was felt desirable, to balance tax concessions and reduced food subsidies in such a way as to leave the Retail Prices Index substantially unchanged.

There are other problems in connection with the food subsidies. Would their removal, for example, lead to a reduction in consumption so great that it would upset the Government policy of guaranteed prices to home farmers and long-term bulk contracts abroad? Again, food subsidies are far more flexible than family allowances. If food prices fall subsidies may automatically disappear, but the removal of allowances or pensions once granted would entail considerable

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political courage. Then, too, if some method has to be employed to compel husbands to augment their wives' housekeeping allowances (which is what all these devices amount to) the food subsidy does more certainly canalise the money in this direction, and ensures that it is not in fact spent on beer and cigarettes.

These, however, are economic and political questions which can safely be left to economists and politicians to debate once they have the essential operational data on which to base their judgment. But without these data they will get nowhere. As Professor Nash wrote to *The Times*, Professor Jewkes' original contention that on balance the food subsidies do not redistribute income in favour of those with large families and low incomes is probably untenable. It is not, however, at all clear that they are the most efficient method of so redistributing income nor, if they are, that they are fixed at the most satisfactory level. This is a problem of some importance at the present time. It will be unfortunate if it is decided without the knowledge of basic essentials which operational research could provide.

O.R. Club

The first meeting of the new session was held on October 31st, when Mr. R. T. Eddison read a paper on *Importing Iron Ore*. The problem was to consider how ports should be equipped and organised so as to minimise importing costs (with particular reference to reducing turn-round time of ships) and at the same time to deal with possible future increases in imports. Statistics of unloading times had been analysed to show the effect of factors such as type of ship, type of ore and unloading equipment on the rate of unloading; and queue theory had been applied to show how changes in the rate of unloading would affect turn-round, etc. Mr. D. Hicks was in the chair.

On December 3rd, Mr. H. A. Sargeaunt read a paper on *O.R. in the Cold War*. He referred briefly to the comparison of O.R. in war and peace and indicated what developments had taken place. In considering the general sphere of usefulness of O.R., he suggested that it could often be helpful in deciding what to do, but that the scientific method has not yet developed a technique for deciding when to do it. This problem of recognition formed the subject of considerable discussion. Dr. O. H. Wansbrough-Jones was in the chair.

Members of the O.R. Club are reminded that the secretary will be glad to receive suggestions for contributions or contributors to the Club's open meeting on *Marshalling and Queueing* in March next.

OPERATIONAL RESEARCH IN THE COAL INDUSTRY

by

DONALD HICKS

Coal has been mined in this country for many hundreds of years, and intensively for the past 80 to 100 years. Output steadily increased to a peak of 287 million tons in 1913, when inland consumption was 193 million tons and 94 million tons of coal were exported. At that time 1.1 million men were employed. After the 1914-18 war the general trend of output was downwards, and it fell to 174 million tons in 1945. Since then the annual output has been rising slowly,

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and is now running at approximately 210 million tons per annum, to produce which 700,000 men are employed in about 1,000 collieries of various sizes and shapes. These bald facts give some idea of the size of the coal industry in Great Britain. The problem of size *qua* size would not be too difficult if conditions throughout the industry were fairly uniform. They are not; conditions vary greatly from coalfield to coalfield and between the individual collieries in a coalfield. First and foremost the mining engineer has to surmount the difficulties which the local geology imposes on him. As the years go by, and as the better and more easily won seams are exhausted, the geological conditions become more complicated and difficult to overcome. It may be an oversimplification to say that the improvements in mining methods in the last 50 years have done little more than keep pace with the increasing mining difficulties. Whether this be true or not, the output per man has changed little during this period, and is now recovering only very slowly from the low figure of 20 cwt. per man-shift of 1945.

Index of Efficiency

The problem facing us today, at a time when manpower is declining, is to reverse a long period trend of falling output. This can be achieved by a better application of existing methods and by devising new and possibly revolutionary methods of mining. In a period of reorganisation and re-equipment, and when some index of efficiency is being sought, other than profit and loss which is no longer an effective criterion for evaluating the performance of each pit, operational research appears to be a useful tool to assist management in selecting the best methods and machines and to help them achieve a higher efficiency of operation. We made a start with operational research in the coal industry in 1948 with one man; the Field Investigation Group now consists of 14 graduate scientists and eight non-graduate trainees. This increase is a measure of the growing call on the services of this form of research.

Operations in the coal industry can be roughly divided into (*a*) getting the coal from the seam, (*b*) transporting the coal to the surface, (*c*) preparing it for the market, and (*d*) selecting and distributing the output to the consumers. Ancillary to (*a*) and (*b*) are the major tasks of securing access to and from the seam, and all that this implies in driving roadways underground and maintaining them against heavy and often unpredictable roof pressures, supporting the roof at the coal face, providing enough air to ventilate the workings and dealing with any water that is tapped en route.

Many of these various operations do not lend themselves easily to routine measurement, and the very nature and growth of an extractive industry has not favoured the establishment of a routine of maintaining records and costs of the component parts of the complex operations which go to make up the whole. When we started, those records which were available were frequently not comparable as between different collieries. For these and other reasons it was soon evident that little would be obtained from the statistical analysis of overall results. The methods of working, the machines used, and the variables associated with the operations, were too numerous to permit such an analysis to be successful. Further, the natural condi-

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tions may have different effects on different parts of the operation and some of the conditions are not immediately measurable.

It was fortunate that the attempt to establish the methods of operational research as a normal tool of management in the coal industry coincided with the big task of reconstruction and development consequent upon nationalisation. The planning engineers, the mechanisation and other engineers who had been called upon to undertake this task were soon posing some fairly straightforward questions. For example, it had long been appreciated that underground haulage systems would have to be greatly improved. Many different systems are available and a choice of the best has to be made for each set of conditions. The engineers wish to know the relative merits of the different methods of transporting coal, be it by diesel, battery or trolley locomotives, by conveyors or by the various methods of rope haulage. This is the kind of question that has been put to the Board's operational research team. Every problem that has been investigated so far has been stated by the production officials and sponsored by them, and the limitation of objective has been of great assistance in enabling the team to develop their methods quickly. It was soon found profitable to work out the methods by starting with a pilot investigation taking no longer than a few months. This has the merit that when the time comes to proceed to the bigger sample there is available not only a tried method but also some rough conclusions which can be tested as the investigation grows, and the added virtue that those for whom the work is done, and those who provide the facilities and the basic data, see quickly the shape of the investigation and the sort of conclusions that are likely to emerge. There has thus been established at many levels a lively interest in the work of the Group and, because the subject investigated has been deliberately limited in scope, there has also been a better chance that the conclusions will be acted upon and the methods of the investigation adopted as a normal procedure of day-to-day management control.

I have described how operational research has been introduced into the coal industry in the hope that this experience may be of some help to those in other industries who are starting to apply the method.

Operational Investigations

So far the Group has been concerned almost entirely with selected underground operations, and mainly with machines and equipment. In most of the investigations the studies have been largely in terms of the monetary costs, although in a few it has been easier and more appropriate to express the operating data on the basis of time and manshifts. Most of the costs measured in manshifts may be converted to monetary costs if it is necessary to compare costs of different natures. In all our studies involving monetary costs adjustments have to be made to allow for differences in wage rates and for changes in prices of machines and spares. This complicates the calculations, but in most cases it is a necessary adjustment of the basic records.

The efficiency of the operations we have studied may be established by the following steps:

(*a*) Statement of the purpose of the operation.

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(*b*) Enumeration of the factors that affect the operation.

(*c*) Choice of the most suitable units for measuring the costs, performance and conditions.

(*d*) Collection of relevant data.

(*e*) Calculation of costs, performance and conditions from these data.

(*f*) Examination of these results: the search for relationships; the formulation of a theory consistent with the results; and the testing of this theory against any fresh data that may be available.

All the problems tackled so far have proved to be tractable when these steps have been followed. In no instance have the operating data required for a thorough investigation been readily available from the normal statistical machine, and consequently the Group have had to spend a good deal of time at the collieries taking measurements of performance and abstracting information from the colliery records. This is very time-consuming, but there are many compensating advantages in that the investigators are brought into that close touch with the actual operations, which is essential if their work is to be fully effective.

An essential of our method is to break down the information in terms of components of the operation studied, so that the effect of the various factors on the total costs of the operation can be assessed. For example, in all our studies of underground haulage installations the costs have been considered under five main headings as follows:

Group I: Costs dependent on the peak hauling capacity of the installation (i.e., locomotives, garages, etc.).

Group II: Costs dependent on mechanical work done (i.e., locomotive maintenance, wages, spares and supplies costs, fuel or power costs, flame-trap cleaner wages, and, for battery locomotives, battery attendant wages and so on).

Group III: Costs dependent on number of shifts worked, wages of drivers, attendants, etc.

Group IV: Costs dependent on length of track (e.g., capital cost and maintenance of track and, for trolleys, the capital costs of trolley wires, etc.).

Group V: Special labour costs (e.g., traffic superintendent, shunters, etc.).

Various methods of haulage can thus be compared, and relationships established, by a combination of traction theory and the results obtained from the surveys. Haulage costs derived from the cost groups represent the average costs which will be obtained in average conditions, and may therefore be used as a standard by which to judge the observed cost of any particular installation. If the cost of one particular component is excessive the reason can be sought and remedied. The accuracy of this method of dividing the costs into groups, each depending on similar factors associated with the haulage system, has been checked by applying the method to individual installations. The agreement is usually good; where it is not, the reasons are sought and action indicated. The component costs may be used also to make a direct comparison of the costs of each

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type of haulage system operating in the same conditions. The costs of the various haulage systems for a variety of conditions can be calculated from the component costs and a true comparison made, and in this way only can the relative merits of the different systems be assessed. Some of the haulage methods which were thought to be obsolete and inherently costly have been shown to be as efficient and just as cheap as some of the newer methods when comparison is made under identical conditions. An account of the first part of these investigations is given by Evans in *Trans. Inst. Min. Eng.*, Vol. 110, page 7, and by Cook and Evans in *Iron and Coal Trades Review*, April 6th and 13th, 1951.

"Drifting" Roadways

An investigation of the driving of underground roadways in rock ("drifting") followed much the same lines, and was studied in terms of four main components, namely (*a*) drilling, (*b*) shot-firing, (*c*) loading the excavated rock and (*d*) supporting the roof. In the haulage investigations the costs were expressed in money; in this study various other units of performance were used, including the yards advanced per week to provide data for planning and progressing new roads, the cubic yards of rock excavated per manshift as a measure of productivity, and finally the shifts per yard of advance as an index of the overall economy.

After the four main components of the drifting operation in a number of roadways had been studied it was possible to calculate the time required for the complete cycle of operations and the productivity in cubic yards per manshift with certain combinations of equipment. Further studies showed that these calculated performances agreed well with actual performances in well-organised drifts. Failures to reach the calculated performance were shown to be due to bad organisation, deficiency in effort, difficulties in handling the stone from the drift and recurrent breakdowns of machines. The average performance of groups of drifts employing similar equipment can be compared with the performance calculated from the averages of the components of each group. In this way an estimate can be made of the general level of efficiency of drifting in the country as a whole. This method, which admittedly has shortcomings, indicated that the average efficiency is much lower than it should be. Where the studies have been extended by a close examination of the individual operations and organisation of the work, marked improvements have been achieved. This is but one useful result; there are others leading to the better choice of machines to achieve a planned rate of advance, and so on.

The haulage and drifting investigations are being continued; many aspects of the problems have not yet been covered, and in any case new machines and improved methods which are continually being developed require investigation. Interesting and profitable ancillary problems are sometimes thrown up. For example, we are greatly concerned to reduce the fire hazard underground from belt conveyors, and much attention has been given recently to non-inflammable substitutes for rubber. Their fire-resisting properties have been examined in the laboratory, but their performance in use underground also has to be fully documented. The operational research team has been

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called upon to do this, and from these studies of the performance of various materials in use there has developed a comprehensive investigation of the factors that determine belt life generally.

Most of the major engineering problems of the coal industry are concerned with the handling and disposal of materials, and not least important are the problems of the disposal of the dirt or stone necessarily excavated during the course of mining. Some of the dirt is stowed underground to help support the roof; the remainder is disposed of on the surface on the colliery tips which are such a feature of the coalfield landscape. Each of these dirt disposal operations is being investigated. Until fairly recently the disposal of dirt underground was done entirely by hand, but mechanical stowing is now practised at a number of pits. Various machines are available, and it is necessary to know their performance under a variety of conditions and how they compare with hand stowing methods. The measurement of direct costs presents no insuperable difficulties, and when completed will indicate which are the most efficient machines and which could be altered with advantage. As with some of the other underground operations there are certain indirect effects, such as improved ventilation and better roadway maintenance, and these are proving most difficult to measure, but until they are better understood the benefits of mechanical stowing cannot be properly assessed. The investigation of the methods and costs of the disposal of dirt on the surface is fairly straightforward; the data enables one colliery to be compared with another, with a view to obtaining a measure of standardisation with the corresponding economies.

I have given a few examples of the sort of work we have found profitable in a deliberately restricted field. There are, even in the limited sphere of machines and their operation, bigger problems than those so far investigated. These will be studied as the methods of investigation are strengthened and their usefulness revealed. There are wider fields still, and in an industry where labour costs play such a big part, the manpower problems, while less tangible than those of machines, are certainly worthy of study by operational research methods. Attendance, accidents and sickness, the effect of environment on health, are a few of the more important, which will in time be tackled by the appropriate agency.

Much that has been done so far has been concerned with the study of the monetary costs of certain underground operations; no attempt has been made by the Group to apply the methods of standard costing to the colliery operations as a whole. Complementary to the work described in this paper, the Board in 1950 decided to supplement with expert advice from outside, the experiments on standard costing which had already been made by their accountants within the industry. The results of these investigations may well prove a great stimulus to improved efficiency all round. A striking feature of the American coal industry is the close link between the cost clerk and the underground supervisor. This is in marked contrast to our own coal industry, where the corresponding official is not well informed by cost statements and daily performance sheets. The experiments in standard costs, while different in nature from the operational research work of the Board, are of the same family, and together these and other methods of assessing and improving efficiency cannot fail to have beneficial results.

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MARKET RESEARCH AND O.R.

by

PATRICK McANALLY

THOSE who practise operational research are notoriously fond of framing definitions. Those who practise market research seem from their performance over the last year or so to have a similar fondness for descriptions. The time is ripe for trying to clarify the relationship between them.

The reason for suspecting a close relationship is not merely that both are forms of research. Operational research was to a great extent nurtured in the wartime needs of the factories and fighting services. With peace, production retained its full importance, but the function of fighting was in some sense superseded by the function of marketing; and with ideas of this sort in mind one is inclined to think of market research as the branch of operational research which is aimed at earning dollars or meeting the sales resistance of the home consumer.

The recent market research publications against which it is proposed to check this idea are:

The Rules of E.S.O.M.A.R.—the European Society for Opinion Surveys and Market Research (1951).

Redmayne and Weeks' *Market Research,* revised and rewritten by R. H. Wadsworth and B. D. Copland (1951).

Principles of Market Research, by A. H. R. Delens (1950).

Social Surveys and Social Action, by Mark Abrams (1951).

The rules of E.S.O.M.A.R. state that membership is open to persons "responsible for some important stage on the systematic polling of people, in connection with commerce, administration or the spreading of information." (For the purposes of this article the expression "market research" is being taken to cover administration and the spreading of information as in the E.S.O.M.A.R. definition: it is also used in this way in the title of the Market Research Society.) E.S.O.M.A.R. also lays down that its full members have to be responsible for "research based on field surveys" and that such surveys must be "based on the theory of sampling in which those interviewed purport to be representative of the universe sampled. Non-representative interviewing is unacceptable for this qualification." It will be seen that under these formulas market research is tied up very tightly with certain techniques for collecting information.

Messrs. Wadsworth and Copland have revised a book which appeared in 1931, and was, as they say, for twenty years the only English textbook on market research. The scope of this book is not coincident with the functions mentioned in the E.S.O.M.A.R. rules. It is intended to cover only commercial applications of market research, but within this field the authors are at pains to emphasise "the unity of a sales intelligence service." By this they mean that they cover not only sample surveys but also the thorough exploitation of sales statistics and of the various published statistics that are relevant. The chapters on sample surveys occupy about half the book and include

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a tabulated scheme for a series of surveys designed to facilitate the launching of a new product.

Mr. Delens' book deals with much the same range of subjects.

Mark Abrams paints with a broader brush. In his book the comprehensive description of sample survey techniques occupies only one chapter. This provides a portrait of a survey carried out in 1937 and 1938 by the Bournville Village Trust. The survey was a large one and involved interviewing 7,161 householders. Its portrait is followed by discussions of the historical background of the modern social survey. The Industrial Revolution led to abuses which were attacked round the middle of the nineteenth century by novelists and essayists like Carlyle, Dickens, Ruskin and Kingsley. By 1875 a new era began when Charles Booth started to ask questions about the population of London, and by 1897 he completed publication of his first series of reports. In 1901 Seebohm Rowntree published his first study of York, and in 1915 Professor Bowley published the results of studies of poverty in the five towns of Reading, Warrington, Northampton, Bolton and Stanley. Bowley introduced sampling methods for this work, and these techniques have been "borrowed" by those who conduct market research in the narrower sense and those who make public opinion surveys. Since 1939 there have been great further developments, which cover surveys of nutrition, old age, town planning and many other administrative problems. In conclusion, Dr. Abrams remarks that "half a century ago the social survey in the hands of Booth, Rowntree and Bowley provided the State with an analysis of poverty which possibly saved Britain from violence and revolution and set her on the road to economic democracy."

These then are the shapes which have been taken by recent books on market research. It remains to examine in more detail the differences that come to light between market research and operational research.

In the first place, it is to be noted that the end product of market research is often a book or a newspaper article. The findings of the social survey pioneers identified by Dr. Abrams were published in books. The results of the ordinary public opinion survey are published in newspapers. These may, and have led to important administrative action. But the same is true of more openly literary works such as the novels of Dickens. Turning to surveys of a more commercial kind, we may think of the surveys of the use of public transport in London and of the Hulton Readership Survey. The results of both have been published in books which were beautified by charts and stylish typography. In so far as market research leads to products of this sort, products which are widely distributed and alluring like advertisements, it seems different from operational research which aims generally at facilitating particular decisions by particular executives.

Preoccupation with sample survey techniques, which is characteristic of market research, is also foreign to the spirit of operational research. It may be noted, for instance, that most writings on how to do market research include signs that it is common to start planning field surveys before it is clear what questions they are supposed to answer. Messrs. Wadsworth and Copland admit this when they say "the first step is to formulate and define the problem which gives

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rise to the decision to undertake an investigation," and Mr. Delens in downright fashion says "It will, therefore, always pay handsomely to think carefully before any research operation." Preoccupation with these techniques also leads people to present surveys as extremely massive affairs. Dr. Abrams' introductory "portrait" mentions over 7,000 interviews, and the only figure mentioned by Messrs. Wadsworth and Copland in their section on the size of the sample is 3,000. Because of the cumbrous nature of such operations these latter authors envisage that for many firms all that will be possible will be "a restricted application to burning problems." They admit that small-scale tests may be used by smaller businesses, but do little to enlarge on this topic, though it is of the most intense practical importance. Research workers surely should be wedded not to field surveys as such but to a scientific approach to all marketing problems. This approach involves clearly formulating and facing the issues that arise and answering them as well as circumstances allow. It must be recognised that there are possibilities of real gain in this, even if the steps taken to find answers have on occasion to be cursory.

From the standpoint of operational research it is of much interest to know just what happens before and after the sample survey techniques are brought into play. Messrs. Wadsworth and Copland insist that it is just as much the duty of the research executive to say when a consumer investigation is not necessary as to recommend one, but we do not get any precise picture of him weighing the pros and cons. The descriptions of the final phases are also disappointing. It appears that after the findings of a piece of work have been made known, there sometimes emerge some "indications of future policy" as in Dr. Abrams' book, and sometimes the marketing problem reaches a sort of fairy tale denouement. Books on market research seldom explain how you decide whether it is worth taking action if only 60 per cent. of consumers are favourable to your product.

This brings us to what is perhaps the most fundamental difference between the attitudes of market research and of operational research, as they appear in print. Messrs. Wadsworth and Copland say "It is the function of the research executive to present facts and only if invited to do so to draw detailed conclusions from them." This is in contrast with Professor Blackett's view that "though research workers should not have executive authority, they will certainly achieve more success if they act in relation to the conclusions of their analysis as if they had it." He advised them to keep silent unless they could recommend action which they felt they themselves would have taken were they executive authorities.

This article has thrown emphasis on the respects in which certain books on market research diverge from the modes of thinking which constitute operational research. There remains, in conclusion, an impression of dichotomy in market research. It is portrayed as consisting of certain elements which procure admittance to E.S.O.M.A.R. and the Market Research Society and also of certain other elements which are not such a source of pride. The attempt to integrate them (into "sales intelligence" work) is not altogether convincing, and if such integration has not been achieved, market research does not very easily take a place as a branch of operational research. For those whose aim it is to hold up a mirror to society and get results in the manner of Charles Booth, this does not matter. But among those to

whom manufacturers look for practical advice an attitude nearer to that of operational research seems a thing to be desired—and indeed it is being adopted by many workers, even if it is not made explicit in the books.

ABSTRACTS

A Method of Studying Underground Costs with Special Reference to Locomotive Haulage Systems and Drifting.

T. A. EVANS (National Coal Board).

Trans. Inst. Mining Engrs., April, 1951, **110** (7), 405

Two of the most important tasks confronting the coal industry are to lower the costs of production and to press on with modernising and reconstructing the industry. Two problems intimately concerned with these tasks are to determine in particular conditions the most economical form of underground haulage and the most efficient methods of driving underground roadways. This paper discusses a method of studying these operations and gives some of the results which have been obtained.

The costs of diesel-locomotive haulage in 21 pits and of battery-locomotives in 13 pits are analysed under various headings, and a method is derived whereby the costs of each form of transport can be calculated in relation to the conditions. Thus the costs of each type under the same operating conditions can be compared and an estimate of the efficiency of any existing installation can be formed. The results of the investigation are also compared with data published for continental installations.

A similar technique has also been applied to a study of the efficiency of various methods of drifting. The results of investigations made in 38 drifts are analysed in terms of the four main components of the operation, namely, drilling, firing, loading, and supporting the roof. The factors affecting efficiency are discussed. As with the locomotive investigation, comparisons are drawn between different types of equipment, and standard performances for various combinations of equipments are calculated.

Costs of Underground Locomotive Haulage Systems.

S. L. COOK and T. A. EVANS (National Coal Board).

Iron & Coal Trades' Review, 6 & 13 *April,* 1951, **163,** 787-792 & 853-857.

This paper refers to the same investigation as that discussed by Evans in *Trans. Inst. Mining Eng., April,* 1951, **110** (7) (see above), to determine the most suitable locomotive for given sets of conditions and to determine the factors which contribute most to the costs.

The comparison is between diesel and battery locomotives. The methods of assessment and comparison of costs are given in detail with actual figures. The costs themselves are considered under five groups—those depending on peak load, on mechanical work done, on length of track, drivers' wages and special labour costs. Maximum

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haulage capacity for each installation is assessed by a formula which includes such factors as maximum gradient, length of single haul and average speed excluding stops. Hence a comparison is made between the costs of the two types of locomotive operating in the same conditions, when it is found that the cost of the battery locomotive is significantly greater than that of the diesel. Reference is also made to trolley locomotives, using published data for the Ruhr.

London and its Passenger Transport System.

F. A. A. MENZLER (London Transport Executive).

J.R. Statist. Soc., 1950, *A (General)*, **13.3**, 298-337

The bulk of this paper is concerned with a comprehensive statement of the descriptive statistics of London passenger transport—underground railways and road services, with somewhat less complete figures relating to the main line railways within the area.

Figures of the population of the Greater London Area are first discussed, with particular reference to its distribution and changes that have taken place over the last 30 years or more. The transport services are next described in terms of route mileage, number of trains, mileage run per head of population and similar statistics, again with comparative figures of earlier years. Finally the traffic itself is analysed according to hourly, daily and seasonal variations, average distance and expenditure on regular journeys, use of alternative means of transport, etc. Some of the latter figures rely on the results of a London Travel Survey as well as routine analysis of ticket sales, etc.

For the most part the figures are presented with little more than a hint of special action which has been taken, or could or should be taken, as a result. It is pointed out, however, that these statistics are collected not to gratify idle curiosity but to serve the needs of administrative and financial control. Statistics are made for London Transport, not London Transport for statistics. The figures given do, in fact, provide essential information for operational research studies which are being undertaken, e.g., into the better use of equipment under service conditions: into the effects of passenger flow on station design and of train loading on the internal layout and door arrangements on rolling stock.

Can Operational Research Help Industry?

T. E. EASTERFIELD (Dept. Scientific and Indust. Research).

Trans. Inst. Engrs. & Shipb. in Scotland, **92** (1948-49), 7-30.

Operational research is defined as "the scientific study of the problems of an organisation 'in operation,' that is, as a going concern." It is thus a staff aid, by which the executive, who must take his decisions quickly and not spend too much time afterwards wondering if they were right, is helped by the scientist, moving more slowly and self-consciously and analysing the more predictable consequences of various possible courses of action. It will always fall to the executive to take the final decisions, on a basis not only of the scientific advice but also on the imponderables and on his administrative experience. Only by the scientist and the executive working together can either really understand what the other is trying

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to do and make a fruitful partnership. Useful by-products of the relationship are the discovery, at times, that an organisation may be pursuing a set of mutually inconsistent aims; and that executives separated by the formal structure of the organisation may be brought together when they are in fact working on parts of a common problem.

Examples of operational research are given: the early developments at Fighter Command, "Planned Flying—Planned Maintenance" at Coastal Command, the productivity studies of the Shirley Institute. Potentially useful fields in industry are discussed: study of productive efficiency, policy on replacement of capital equipment, study of the needs and habits of the consumer (including the abuse he may be expected to give the products he buys), optimum degree of standardisation.

It is emphasised that it is the relationship of the scientist to the executive that is the really important thing. Statistics was probably the most frequently used single tool, but contributions were made during the war by workers trained in many other disciplines. It is pointed out that a statistics section tends to differ in nature from an operational research section, each having its complementary virtues.

In the ensuing discussion, one speaker suggested that the executive has been doing, or ought to be doing, operational research all the time. The author disagreed with this, on the ground that the executive has neither the time nor the outlook to do research; the research function is a heightening of the commonsense approach that can usefully become a specialised staff function in a large organisation.

Operational Research in the Rubber Industry.

J. R. SCOTT (Research Ass. of Brit. Rubber Mfrs.).

J. Rubber Research, Sept. & Oct., 1951, **20** (9 & 10), 63-70.

The meaning of O.R. is discussed following the definition "O.R. is a scientific method of providing managements with data upon which to base executive decisions." The ultimate aim of O.R. in industry is stated as to improve its competitive power by (i) increasing production, (ii) cheapening production, (iii) improving quality of the finished product. The choice of suitable projects for O.R. is considered under each of these headings.

For increased or cheaper production the productivity survey is suggested as the basic form of investigation. Such surveys are best carried out on individual processes rather than on overall production, although the possible interdependence between succeeding processes must not be forgotten. The choice of process for study depends on the importance of the process in the final cost analysis of the product; the possibility that the process may be a bottleneck; and the possibility of obtaining valid comparisons between factories. A number of processes are suggested as suitable for study by these criteria.

In improving quality the role of O.R. is to show where there is a need for improvement and what degree of improvement is possible, rather than how to achieve it. The R.A.B.R.M. has carried out surveys to compare the quality of a great variety of rubber products. Wide variations have been found in the quality of the same article produced by different manufacturers. Examples are given.

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Finally, an investigation is described regarding the possibility of eliminating the use of carbon disulphide in the cold-curing of fabrics. Samples of fabrics of two different weights cured by three different methods were submitted to garment manufacturers for assessment of quality. Such assessments are necessarily subjective and an opportunity was taken in designing the experiment to determine what physical characteristics played the greatest part in deciding the order.

Twenty-five Years of Research in Vocational Guidance.

PERCIVAL SMITH.

Occupational Psychology, January, 1951; **25,** 35-43.

This paper surveys the work of the Birmingham Education Committee in vocational guidance and gives the results of following up the careers of children advised by them. The experiments, which were on a large scale and carried out with careful "control groups," show conclusively that scientific methods of vocational guidance improve very considerably the advice that can be given to children leaving school. Those so advised, and who followed the advice, were in general more happily placed, more permanently settled, and were of greater value to their employers than children given vocational guidance in the usual way. The paper also sketches how the large-scale experiments were organised and the way in which large numbers of teachers were trained to collect the necessary information.

OPERATIONS RESEARCH IN BUSINESS AND INDUSTRY

A Seminar held at the Case Institute of Technology, Cleveland, Ohio, U.S.A., November 8th to 10th, 1951

THIS Seminar, a three-day conference, was planned and run by the staff of the Case Institute, led by Professors C. West Churchman and Clay H. Hollister.

As the Seminar was the first of its kind, its promoters had to decide on objectives and policy and to agree on a working definition of operations research. It is clear from the type of speaker chosen by the organisers and also from the invitations to attend as delegates, and more notably from the omissions in both cases, that the decision taken was to treat O.R. mainly on a rather high scientific level. The principal speakers were Professors Hollister and West Churchman, Professor Littauer and David Hertz of Columbia, Philip Morse and A. A. Brown of M.I.T., Russell Ackoff of Project Doan Brook, and the writer, who presented two complementary papers expressing different facets of British opinion and work. One of these papers was by Dr. T. E. Easterfield and the other by himself.*

It is fair to say in connection with the above list, that the writer's apprehension that the papers and discussions would be too academic, and that there would be too much harking back to war O.R., was not justified. There was a certain amount of what one delegate called "polishing of medals," but this was not overdone and the papers and discussions were, for the most part, of a practical character,

* Published in *The Engineer* for December 21st, 1951.

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searching for ideas capable of being put into use in present-day business and industry.

The subjects of the main papers included examination of the purpose and techniques of O.R. and extensive descriptions of actual work being carried out in present-day industry. Contributors to this section included Dr. A. A. Brown on work for a large department store; Professor Littauer on a rational approach to time, motion study and job evaluation; and the writer on various jobs carried out in the British steel industry.

In addition to the main meetings at which full-length papers were presented and discussed, there were two afternoons devoted to what we should call discussion groups but which the Americans call "clinics" ("pertaining to a patient in bed"—Nuttall's Standard Dictionary).

There emerged from the Seminar a measure of agreement on a definition resembling that on which there is also some agreement in Great Britain. The pithiest expression of this definition was, "the application of the approach of the physical sciences to business problems, with particular emphasis on probability and statistics."

On the subject of who shall carry out O.R. in industry there was less agreement. It was the view of some speakers that since pure scientists such as physicists, mathematicians and others were highly successful in the war O.R., and since present-day techniques involve such methods as Von Neumann's "Theory of Games," complex problems in probability theory, etc., which demand a deep knowledge of mathematics, O.R. can only be successfully carried on by the same type of scientist. An alternative point of view was that the opportunities for the more learned forms of O.R. in industry may be limited; that O.R. may and often does call for an understanding of techniques such as time-study, accountancy, etc.; and that, above all, it demands continual practice of advanced practical psychology, since there cannot be success unless the O.R worker has the co-operation and friendship of the "practical" man whom he is trying to help. This particular point emerged strongly during the afternoon "clinics." The writer was in charge of one group, and it was clear that the main questions in the minds of the delegates were:

(1) What is O.R.?

(2) Can I apply it in my own organisation?

A considerable proportion of those attending the Seminar were engineers—mechanical, chemical, etc.—many of whom had experience of statistical quality control. The writer's point of view, as expressed to men of this type, was that O.R. need not be confined to the high-ranking scientist, and that quality control can form a useful basis for expansion into O.R. No official pronouncement was made on this subject, so this remains a personal opinion.

A. W. SWAN.

We learn that a sequence of courses in operational research is beginning at Columbia University, New York, in the Spring term of 1952, under the direction of Professor Littauer and David Hertz.

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